STATE OF CALIFORNIA
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DIVISION OF WATER RESOURCES
EDWARD HYATT, State Engineer

Reports on State Water Plan Prepared Pursuant to Chapter 832, Statutes of 1929

BULLETIN No. 31

SANTA ANA RIVER BASIN

A plan for flood control and conservation of waste water.
Present and future importation requirements.
Sources of outside supply.
Salinity intrusion.

1930

80998

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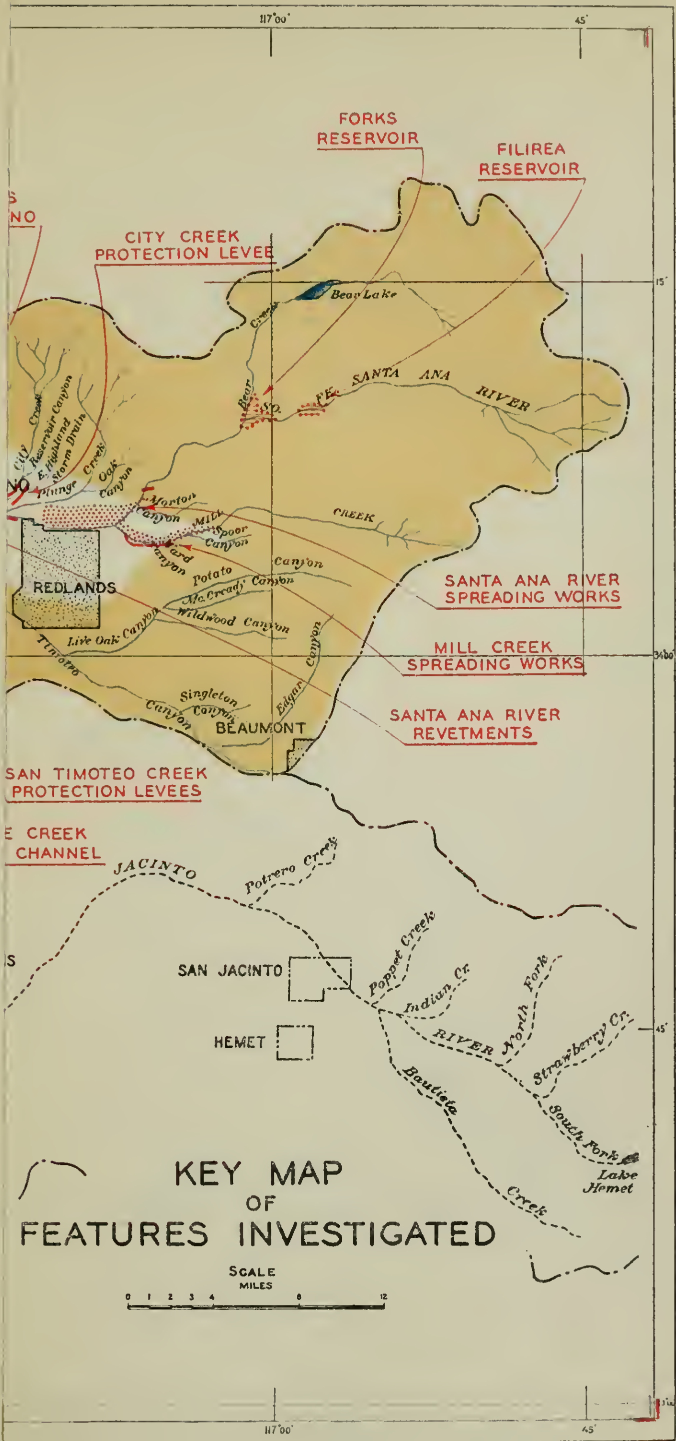
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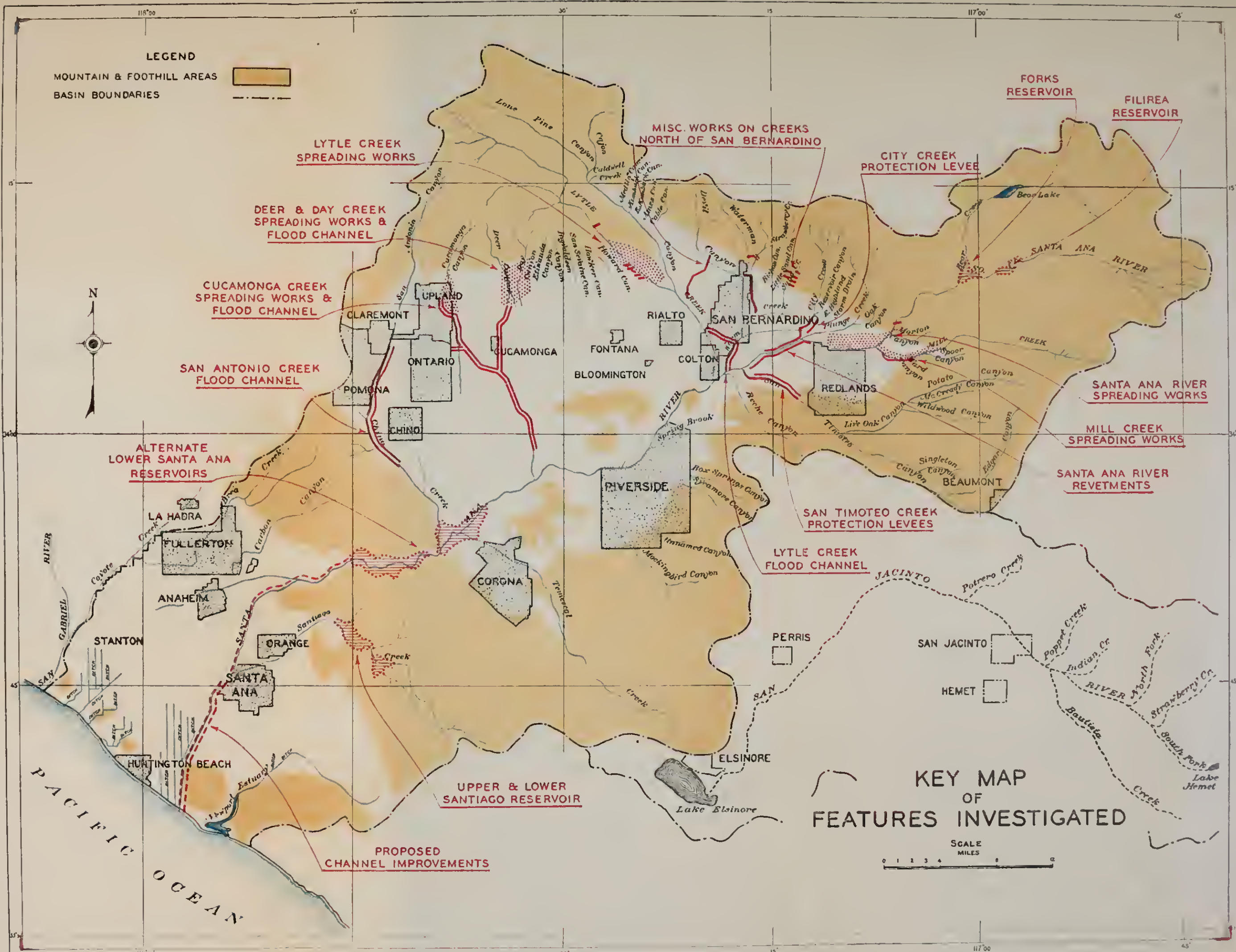

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ACKNOWLEDGMENT

The following special committees representing different sections of Santa Ana Basin cooperated with the State in working out the plan for flood control and conservation in the sections which each represents. While it is not intended to imply each member of each committee is in full accord with the details of the plan herein proposed, the advice and assistance of the several committees was at all times readily given and was of great value.

CUCAMONGA BASIN

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CHAPTER 832, STATUTES OF 1929

An act making an appropriation for work of exploration, investigation and preliminary plans in furtherance of a coordinated plan for the conservation, development, and utilization of the water resources of California including the Santa Ana river, Mojave river and all water resources of southern California.

[I object to the item of $450,000.00 in section 1 and reduce the amount to $390,000.00. With this reduction I approve the bill. Dated June 17, 1929. C. C. YOUNG, Governor.]

The people of the State of California do enact as follows:

SECTION 1. Out of any money in the state treasury not otherwise appropriated, the sum of four hundred fifty thousands dollars, or so much thereof as may be necessary, is hereby appropriated to be expended by the state department of public works in accordance with law in conducting work of exploration, investigation and preliminary plans in furtherance of a coordinated plan for the conservation, development and utilization of the water resources of California including the Santa Ana river and its tributaries, the Mojave river and its tributaries, and all other water resources of southern California.

SEC. 2. The department of public works, subject to the other provisions of this act, is empowered to expend any portion of the appropriation herein provided for the purposes of this act, in cooperation with the government of the United States of America or in cooperation with political subdivisions of the State of California; and for the purpose of such cooperation is hereby authorized to draw its claim upon said appropriation in favor of the United States of America or the appropriate agency thereof for the payment of the cost of such portion of said cooperative work as may be determined by the department of public works.

SEC. 3. Upon the sale of any bonds of this state hereafter authorized to be issued to be expended for any one or more purposes for which any part of the appropriation herein provided may have been expended, the amount so expended from the appropriation herein provided shall be returned into the general fund of the state treasury out of the proceeds first derived from the sale of said bonds.

FOREWORD

This report is one of a series of bulletins on the State Water Plan issued by the Division of Water Resources pursuant to the provisions of Chapter 832, Statutes of 1929, directing further investigations of the water resources of California. The series includes Bulletins Nos. 25 to 36 inclusive. Bulletin No. 25, "Report to Legislature of 1931 on State Water Plan," is a summary report of the entire investigation.

Prior to the studies carried out under this act, the water resources investigation had been in progress more or less continuously since 1921 under several statutory enactments. The results of the earlier work have been published as Bulletins Nos. 3, 4, 5, 6, 9, 11, 12, 13, 14, 19 and 20 of the former Division of Engineering and Irrigation, Nos. 5, 6 and 7 of the former Division of Water Rights and Nos. 22 and 24 of the Division of Water Resources.

The cost of importing a supply from sources outside the Pacific Slope sufficient in magnitude for Santa Ana Basin precludes serious consideration of such importation for Santa Ana Basin alone. The South Pacific Coast Basin, of which Santa Ana Basin is a part, considered as a whole must import water to supplement its deficient local supplies and the Metropolitan Water District of Southern California is actively pressing a project for this purpose. Santa Ana Basin can participate in this and obtain supplemental supplies.

This is briefly considered herein but the principal part of this bulletin deals with a plan for flood control on Santa Ana River and tributaries and conservation of the present flood wastes for use in Santa Ana Basin.

CHAPTER I

SUMMARY AND CONCLUSIONS

Santa Ana Basin is a part of what has been designated the "South Coastal Basin," which includes the drainage areas of Los Angeles, San Gabriel and Santa Ana rivers (except San Jacinto River basin, a tributary of Santa Ana River), the small streams on the coast west of Los Angeles and the coastal plains of Orange and Los Angeles counties. The water supply of the South Coastal Basin is insufficient and to provide a complete supply, water must be imported from distant points. The Metropolitan Water District was organized for this purpose and has made an exhaustive investigation of a plan to transport water from the Colorado River. The state also has investigated a plan for bringing water from Colorado River to serve the entire coastal area of southern California south of the north line of Ventura County.

Thus, the situation as to an outside supply for Santa Ana Basin is different from that in San Joaquin Valley discussed in previous bulletins. If the plans of the Metropolitan Water District are consummated, a supply believed to be sufficient for present and prospective shortage in the South Coastal Basin will be brought into the area. In view of this, no additional investigation of outside sources sufficient for the ultimate needs of Santa Ana Basin was thought to be justified for this report. There have been considered, however, two other possible importations for Santa Ana Basin from nearby sources. One possibility is Mohave River and the other is sewage from the Los Angeles metropolitan area. The first is insufficient for present needs of Santa Ana Basin. Furthermore since the water supply of Mohave Basin is not sufficient for the irrigable land in that basin the transfer of water from it would limit its development. The second, while an importation so far as Santa Ana Basin is concerned, is a transfer of water from one part of South Coastal Basin, with insufficient supply as a whole, to another part. For these reasons these possibilities are in a different category than the possibilities investigated for the San Joaquin Valley, to which it is proposed to transfer water from the Sacramento Valley, where there is a surplus, to upper San Joaquin Valley, where there is a general shortage such as exists in South Coastal Basin.

The body of this report deals entirely with a plan for conserving local supplies and preventing flood damage. Water supply and basin shortage were discussed at length in Bulletin 19, "Santa Ana Investigation," issued in 1929, and the salient items are briefly mentioned in this chapter. The possible outside supplies also are considered and the approximate cost and possibilities are given. This chapter therefore, is more than a review of the body of the report. It briefly digests not only the body of this report, but also certain parts of Bulletin 19, the approximate results of the investigations of Metropolitan Water District in so far as they have been reported to date (November 30, 1930), and the results to date of certain research work which is still in progress by agencies other than the state.

Statement of Problem.

The water problem which confronts Santa Ana Basin as a whole may be subdivided into the following:

(1) Conservation of water now wasting.
   (a) Flood wastes into ocean;
   (b) Miscellaneous wastes into ocean from drains, sewers, etc;
   (c) Waste by evaporation and transpiration from seeped lands.

(2) Flood control.

(3) Importation of water from outside sources to provide for
   (a) Present shortage in underground basins;
   (b) Additional draft on the underground basins as unirrigated lands overlying the underground reservoirs come under cultivation;
   (c) Lands in the valleys not overlying underground reservoirs and also lands lying on hills and foothills.

(4) Protection from salt water intrusion into the pumping area of the Coastal Plain.

Except as to the last, the above list gives the logical sequence of steps in the problem, although in point of time they may overlap and one may merge with another. Protection from salt water intrusion is a matter of immediate concern. Conservation of flood wastes and flood protection go hand in hand.

Description of Basin.*

Santa Ana Basin is divided sharply into two parts. The upper is called herein Upper Santa Ana Valley or Upper Valley and the lower is called Lower Basin. The division is made by the Santa Ana range of mountains through which Santa Ana River has cut its way. The canyon thus formed is called Lower Santa Ana Canyon. Chino Basin is the west end of the Upper Valley. Reference to the frontispiece will make the matter clearer than a description possibly can. Chino Basin † has two small subbasins at its northern margin named Pomona and Cucamonga, respectively, but not shown on the frontispiece. The northeast part of Upper Santa Ana Valley is known as Upper Basin and can be separated into two parts, the western dominated by Lytle Creek and the eastern by Santa Ana River.

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* See frontispiece.

† Chino Basin was called Cucamonga Basin in Bulletin 19. The change in name is made to accord more nearly with local usage. Cucamonga Basin is often called Upper Chino Basin.

Flood Control and Conservation of Flood Waste.

The following features would in their entirety afford flood control and practically complete conservation of flood wastes:

		Estimated Cost
Upper Santa Ana Valley.		
West End.		
San Antonio Creek flood channel	$317,500	
Cucamonga Creek spreading works	241,400	
Deer and Day Creeks spreading works	339,700	
Cucamonga, Deer-Day, and Ontario flood channel	768,700	
		$1,667,300
Lytle Creek.		
Debris dam	395,300	
Possible gravel storage in mountains	104,700	
Spreading and revetment works	358,300	
Flood channel	277,200	
		1,135,500
Miscellaneous Creeks North of San Bernardino.		
Devil's Canyon	40,200	
Waterman and East Twin Creek	42,900	
Little Sand Creek	20,200	
Sand Creek	25,600	
City Creek	49,500	
		178,400
Santa Ana River.		
Spreading works	350,400	
Debris dam	255,800	
Possible gravel storage in mountains	244,200	
Bank protection	219,300	
		1,069,700
Mill Creek.		
Spreading works	42,800	
		42,800
San Timoteo Creek.		
Flood channel and protection	140,800	
		140,800
Total Upper Valley		$4,234,500

Lower Santa Ana Basin.

(Costs given under this heading are only approximate because they are under more detailed investigation by a separate board of engineers retained by Orange County Flood Control District.)

Reservoir in Lower Santa Ana Canyon	$10,000,000
Channel improvement and acquisition on Santa Ana River below Lower Santa Ana Canyon, Reservoirs on Santiago Creek	2,000,000
Total Lower Basin	$12,000,000
Grand Total	$16,234,500

The construction of these should give complete protection from damage from a larger flood on the river and each tributary than any yet recorded in the Santa Ana Basin, in so far as needs can be seen at this time. They would not be interdependent in their effect on floods. The works in the Upper Valley would be of local benefit and would not help the situation on the Lower Basin. The reverse obviously also would be true.

In addition to flood control, practically all the water now wasting into the ocean through the channel of Santa Ana River would be salvaged. The estimated average annual salvage of the waste of the past thirty-six years is 30,000 acre-feet out of an estimated average annual flood waste into the ocean of 33,000 acre-feet. As the annual discharge of these streams is extremely erratic there would be some years in which the amount of water saved would be negligible and others in which it would be very large. The amount wasted in 1916 is estimated at 286,000 acre-feet and this is the only year in the past thirty-six when all the waste could not have been saved.

It is thought probable that about 25 per cent of the water thus salvaged would be available in the Upper Santa Ana Valley and the remainder in the Lower Basin only; *i. e.,* the Coastal Plain of Orange County. A very large proportion of the salvage in the Upper Valley would be accomplished by spreading the flood waters on Santa Ana Cone at the debouchure of the river from the mountains. While no more water could be salvaged in total by constructing reservoirs in the mountain headwaters of either the river or the tributaries, more could be made available in the Upper Valley by such reservoirs.

Filirea reservoir on Santa Ana River is the cheapest and, by construcing this to its maximum capacity of 4000 acre-feet, it is estimated an average of 2400 acre-feet annually more could be made available in the Upper Valley at a capital cost of $670 per acre-foot. This would not aid in protection from major floods, nor do data indicate that there is a shortage of supply in the basin along the Santa Ana River in the eastern part of the Upper Valley, to which area the water so salvaged would be available. The cost of other reservoirs in the mountain headwaters of either the main river or its tributaries is much greater per acre-foot of additional salvage. The cost is exceptionally large on the tributaries, and, like Filirea, the function of such reservoirs would be to transfer the location where the water would be available, from the Lower Basin to the Upper Valley. As data indicate that there is no long time average shortage of replenishment in the eastern part of the Upper Valley which is supplied partly or wholly by Santa Ana River, water salvaged there would reach the Lower Basin until such time as demand in that part of the Upper Valley exceeds replenishment.

The addition to the supply of Chino Basin by the works listed would be very small because there is little flood water to save. Even without such works, only a small part of the floods escape on the surface from the basin to Santa Ana River. The works on the tributaries entering Chino Basin before enumerated, could be expected to do all that is practicable and should help the situation in the small basins at the upper margin of Chino Basin by causing more percolation there.

A board of engineers retained by Orange County Flood Control District is now restudying the formerly proposed program of the district. Only very approximate costs of the items on the Lower River are given in the foregoing list and the items themselves are included subject to any recommendations which may be made by the board of engineers just mentioned.

The works in the Upper Valley would be largely for spreading and their magnitude would be greater than any yet attempted. Construction of spreading works is different from much other engineering construction and can proceed progressively. In view of this and the possibility of obtaining new and valuable information from observation of the first unit of a particular spreading project, which would make it possible to change the next unit to secure better results, the work in the Upper Valley should proceed on a program covering several years to give opportunity for observation. This is true also with the debris dams and utilization of gravels for storage in the mountains. If experience justifies a larger program of construction of debris dams and gravel storage in the mountain sections of Lytle Creek and Santa Ana

River than has been included in the foregoing list, additional work should be done.

Conservation of Miscellaneous and Intangible Wastes.

Water escapes into the ocean from the Lower Basin through the joint sewer outfall of the cities of Santa Ana, Anaheim, Orange, Fullerton, Placentia, La Habra and Garden Grove, through drains and swamps along the coastal fringe and by floods from the miscellaneous creeks in Orange County not tributary to Santa Ana River, but which, in the main, contribute to the water supply of the area also supplied from Santa Ana River. Water is lost along Santa Ana River by wasteful evaporation from wild plant life. The total amount of all these wastes was estimated at 67,000 acre-feet annually in Bulletin 19. Some of this, such as drainage and sewage, can be readily salvaged. Salvage of floods from the creeks is embraced in the plans so far proposed by the Orange County Flood Control District. Salvage of the wasteful evaporation from wild plant life along the river from Colton, in the Upper Valley, to Yorba, at the head of the Lower Basin, can be accomplished only by lowering the water plane or otherwise destroying the present vegetation. This is a more complex problem than is salvage of the wastes previously mentioned, and it is unlikely that it can be accomplished in total. However, it may be that sufficient of this would be saved to bring the total of easily salvaged water to an amount equal to half the total estimated waste, or approximately 33,000 acre-feet.

Present Basin Shortage and Supply.

The annual recharge averaged over the past thirty-six years is less than the present demand, although from present data a reliable evaluation of the deficiency is difficult. Bulletin 19, with data available up to the beginning of 1928, estimated that the demand at that time exceeded average recharge by 83,000 acre-feet annually. The demand has increased since then, and on the basis of the foregoing estimate the present overdraft should be about 100,000 acre-feet. Certain other data, however, do not indicate so large an overdraft. The estimated shortage may be compared with the total probable salvage of present wastes, estimated at 63,000 acre-feet annually, of which 30,000 acre-feet is flood waste through Santa Ana River channel and the remainder made up of miscellaneous wastes noted in the foregoing section. The shortage is concentrated in Chino Basin and the Coastal Plain. Lytle Creek Basin may also have a shortage, even with greater pumping lifts than at present.

Bulletin 19 states the area using water in Santa Ana Basin is 368,000 acres (1928), that the average rate of increase in development had been 10,000 acres per year since 1912 and that there are 226,000 acres as yet uncultivated, of which 186,000 acres are on the valley floor. Where this overlies a water plane from which pumping is possible it has a water right and, as it is developed, will draw on the already deficient underground supplies.

Salt Water Intrusion.

This is a matter which as yet is not serious in Santa Ana Basin, although certain wells near the ocean are pumping salt water. A further lowered water table in the Coastal Plain will increase the danger of such intrusion. One certain way to guard against it is by maintaining the water table at sufficient height, with consequent possible loss of water into the ocean. Regardless of the results of mathematical calculations comparing supply with demand on the Coastal Plain, there must be sufficient water to guard against intrusion and, so far as known now, surplus is the only barrier which will keep salt water out. The amount necessary is indeterminate with present knowledge.

POSSIBLE SUPPLIES FROM OUTSIDE

Sewage.

The only sewage outfall of magnitude in the South Coastal Basin is that of Los Angeles City at Hyperion. Others are those of the harbor cities, the Los Angeles County Sanitation District and Orange County cities previously noted. The total quantity is now 161,000 acre-feet annually, which is more than sufficient to supply the present deficiency in Santa Ana Basin. The annual increase in sewage is considerable. Preliminary estimates indicate sewage from Los Angeles can be purified sufficiently for irrigation use and transported to the Santa Ana River wash at Yorba, just below Lower Santa Ana Canyon, or can be put into main conduits of the ditch companies in Orange County at a cost of not more than $15 per acre-foot, exclusive of amortization. The cost of purification in this estimate is based on costs found in experimental installations. This is the cheapest source of foreign sewage for Orange County as a whole. Although estimates have not been made, it is believed it would cost from two to two and one-half times as much to deliver it in Chino Basin from the same source.

There are two difficulties with sewage utilization. One is the natural prejudice against its use on the part of those who do not understand the matter, but time and education should gradually eliminate this. The other difficulty lies in getting a guarantee from the organization which produces the sewage that it will not dispose of it in some other way. Without such guarantee construction for its utilization would not be justified.

Metropolitan Water District.

The act authorizing formation of the Metropolitan Water District provides that any water district incorporated for service of water in other than municipal territory can join the district and that water shall be prorated in accordance with assessed valuation of the different units. The western boundary of San Bernardino, Riverside and Orange counties coincides closely with the western boundary of Santa Ana Basin. Including Los Angeles County, practically the entire assessed valuation of the four counties is in South Coastal Basin, comprising the area in which the Metropolitan District is functioning at the present time. Therefore, the total assessed valuation of the four counties can be used as a fairly accurate measure of the amount of water Santa Ana Basin will receive should it organize and join the district. The three eastern counties have an assessed valuation which, when adjusted to conform with that of Los Angeles County, is about 10 per cent of the total. On the same adjusted basis the assessed valuation of the three counties is about 18 per cent of the total found by adding the assessed valuation of the three counties to the assessed valuation of all the units in Los Angeles County now in the district.*

The Metropolitan District has examined the details of a conduit from Colorado River of 1500 second-foot capacity in order to prepare for a bond election for financing its construction. Although a route has not at this writing been definitely selected, yet it is assumed for discussion in this report that an aqueduct of this capacity will be built and that with the aqueduct functioning to capacity the cost of water laid down in South Coastal Basin will be $25 per acre-foot without amortization.

On the basis of the foregoing assumption, if Santa Ana Basin should form a water district or districts embracing the entire basin, and join the Metropolitan District, it would receive at least 150 second-feet of water from the Metropolitan District, assuming, of course, that the entire agricultural and urban area of South Coastal Basin joins the district and that the ratio of assessed valuations remains as at present. If no more than the present units in Los Angeles County join the Metropolitan District, Santa Ana Basin would receive 270 second-feet. The first quantity gives 109,000 acre-feet annually and the second 195,000 acre-feet annually.

While the smaller of the two quantities is believed to be sufficient for present overdraft, there will be further overdraft, due to increased development, before the district's aqueduct can be completed. However, if local wastes are salvaged in the meantime it should be possible to keep pace with the increased demand in the basin until the aqueduct shall have been completed.

The annual acre-foot cost will be the same in both cases when the total amount is used, provided cost is based on assessed valuation, but, unless demand equals the larger supply when the water is brought in, the cost per acre-foot of imported water actually utilized will be larger with the larger quantity. This will be compensated for, in part at least, by smaller pumping lift, due to higher water plane caused by surplus water. In addition, this surplus will be valuable as insurance against intrusion of salt water into the Coastal Plain.

While ultimate needs in Santa Ana Basin will be greater than the maximum of the foregoing quantities, plus local salvage, it will be many years before the ultimate demand is reached. The addition of a large supply to the area will relieve the present tension and make it possible to plan the next step. It may be possible, under such conditions, to introduce economies in methods of obtaining present supplies which now are handicapped by legal strictures. For future needs it may be found that there is a permanent surplus of aqueduct water which may be purchased, that the Metropolitan District Act may be changed to provide at least partial proration in accordance with needs, instead of in accordance with assessed valuations, and that utilization of sewage or other reclaimable wastes will be possible in any area because of the large general supply, without handicap due to lack of ownership as is the case at present when use of sewage from the metropolitan area is proposed.

* September 1, 1930.

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In the above, Santa Ana Basin is treated as a whole. For Chino Basin as a whole, however, the only part of the program which would be of material benefit is importation of water, but an importable supply available without complications is difficult to find. It may be that wet years will relieve the present difficulties in the upper margin of Chino Basin or it may be that, with assurance of large supplies in the future by importation for the whole Santa Ana Basin, a temporary supply can be procured from some source not now available.

Mohave River

Mohave River rises on the north side of San Bernardino range and is lost in the sinks of Mohave Desert. Its principal forks in the mountains are West Fork and Deep Creek (East Fork), which unite near the base of the mountains. The average annual run-off from the mountain headwaters was estimated at 98,000 acre-feet in Bulletin 5, "Flow in California Streams," Division of Engineering and Irrigation, State Department of Public Works.

Preliminary estimates indicate it is feasible, from the physical standpoint, to control the run-off of the river so that an average annual amount approximating 70,000 acre-feet can be diverted through the mountains to Santa Ana Basin. Diversion of such an amount would require purchase and control of Arrowhead Lake and diversion of some of the tributaries of Deep Creek into it. Without control of Arrowhead Lake an average annual amount estimated at approximately 60,000 acre-feet can be brought to Santa Ana Basin.

The approximate construction cost of diverting 60,000 acre-feet to Santa Ana Basin and distributing it along the upper margin of the basin from San Bernardino to Pomona is estimated at $9,000,000. The diversion of this amount would involve acquisition of water rights on Mohave River to an unknown extent and the complete cost would be greater than that sum.

The practicability of the engineering features of this plan depends on the feasibility of Forks Reservoir, the foundations for which have not been explored. Forks Reservoir lies on West Fork just above its junction with Deep Creek. It has been surveyed to a capacity of 113,000 acre-feet with water surface 160 feet above stream bed. The cost per acre-foot of water diverted to Santa Ana Basin and distributed along the upper margin of the basin can not be estimated accurately because of lack of knowledge as to cost of purchasing rights. After paying for this, the cost might be as large as that for water obtained through the Metropolitan Water District.

Estimates of cost of diverting other smaller amounts have not been made, but indications are that such amounts can be diverted from West Fork to Santa Ana Basin at reasonable cost for construction features. In this case also, nothing is known as to the cost of purchasing rights. Diversion of an average annual amount of from 15,000 to 20,000 acre-feet would leave sufficient water for present development in Mohave Basin, plus some expansion.

The present irrigated area in Mohave Basin is approximately 8000 acres. The sixth biennial report (1916–1918) of the Department of Engineering, California, gives the gross agricultural area in Mohave Basin as 325,000 acres. Two irrigation districts on the east and west mesas above Victorville, covering a gross area of 100,000 acres, have been proposed. The biennial report states that the soil is of good quality. One of these irrigation districts is being promoted at present, but the other is quiescent.

Diversion of any part of Mohave River to Santa Ana Basin will curtail irrigation possibilities in Mohave Basin. In addition to removing water from an area of deficient supply it would transfer it to an area which, although short of water now, has potentially a complete supply through plans for other importation.

The utmost possible diversion from Mohave River, together with salvage of local waste in Santa Ana Basin is believed to be more than sufficient to offset the present shortage in Santa Ana Basin, but the margin is not large. Continued development in Santa Ana Basin would have to depend on still other outside supplies.

The Mohave River, if entirely diverted to Santa Ana Basin, would relieve the present shortage in Chino Basin and around San Bernardino, but it is believed other supplies would eventually have to be imported into this area, even if Mohave River were brought in and used entirely for it.

CONCLUSIONS

1. Present underground water supplies in Santa Ana Basin are overdrawn, even when long time average, instead of the present period of deficient replenishment, is considered.

2. Salt water intrusion from the ocean into the pumping fields of the Coastal Plain is rendered possible by this overdraft.

3. Conservation of flood wastes into the ocean, of miscellaneous drainage, sewage and other wastes into the ocean, and of intangible wastes from seeped land would help this situation, but would not be sufficient. Importation of an outside supply also is neccessary to provide for present shortage, to provide for increases in demand and to guard against salt water intrusion.

4. Conservation of flood waste would also give protection from damage by floods. Conservation of flood waste and flood protection go hand in hand in Santa Ana Basin.

5. Construction of the items listed under the heading "Flood Control and Conservation of Flood Waste" would give protection against a larger flood than any yet recorded on the Santa Ana River and its tributaries and would conserve 90 per cent of the present flood waste into the ocean through the channel of Santa Ana River.

6. Conservation of other miscellaneous and intangible present wastes of water also is necessary, but difficulties lie in the way of salvage of a considerable part of such wastes.

7. Salvage of flood wastes will give negligible aid to Chino Basin as a whole and inadequate help to the Lower Basin (Coastal Plain).

8. Salvage of other miscellaneous wastes will help the situation in the Coastal Plain to a considerable extent.

9. To obtain a full supply for present and future development, water must be imported from outside.

10. Salt water intrusion into the Coastal Plain can be prevented by keeping the water plane near the ocean at a high level, which may mean importing water in addition to that necessary to supply irrigation and other needs.

11. Injurious concentration of alkali in the underground water especially near the ocean can be prevented only by a supply in excess of consumptive use by plant life, etc., so that sufficient water to carry off the alkali can drain into the ocean.

12. Salvage of local wastes is necessary at once unless sufficient outside supplies can be brought in immediately and made available in localities where shortages exist.

13 Any plan for bringing in outside waters for the agricultural areas of Santa Ana Basin involves organization of the area into one or more districts.

117°00'
45'
15
34°00'
Bear Lake
Creek
Bear
SO. FK. SANTA ANA RIVER
BASIN
Plunge
Oak Canyon
Morton Canyon
MILL CREEK
Spoor Canyon
Ward Canyon
Potato Canyon
McCready Canyon
Wildwood Canyon
Live Oak Canyon
Edgar Canyon
Timoteo Canyon
Singleton Canyon
REDLANDS
BEAUMONT
JACINTO
Potrero Creek
SAN JACINTO BASIN
SAN JACINTO
HEMET
Poppet Creek
Indian Cr.
RIVER
North Fork
Strawberry Cr.
South Fork
Lake Hemet
Bautista Creek
MAJOR BASINS OF SANTA ANA BASIN
SCALE
MILES
0 1 2 3 4 8 12
117°00'
45'

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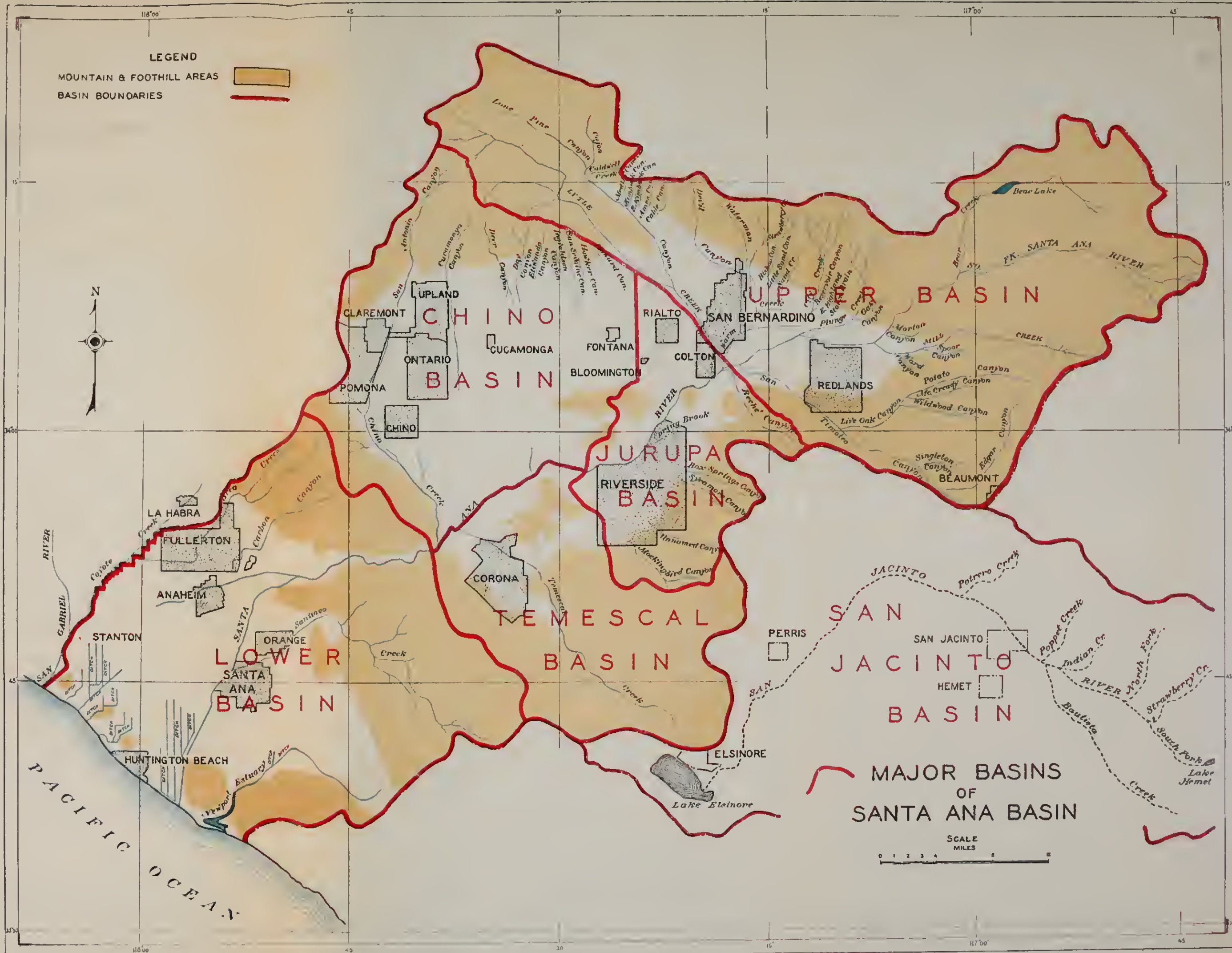

LEGEND
MOUNTAIN & FOOTHILL AREAS
BASIN BOUNDARIES
MAJOR BASINS OF SANTA ANA BASIN
SCALE MILES
CHINO BASIN
UPPER BASIN
JURUPA BASIN
TEMESCAL BASIN
LOWER BASIN
SAN JACINTO BASIN
PACIFIC OCEAN
UPLAND
CLAREMONT
ONTARIO
POMONA
CHINO
CUCAMONGA
FONTANA
BLOOMINGTON
RIALTO
COLTON
SAN BERNARDINO
REDLANDS
BEAUMONT
RIVERSIDE
CORONA
LA HABRA
FULLERTON
ANAHEIM
STANTON
ORANGE
SANTA ANA
HUNTINGTON BEACH
ELSINORE
PERRIS
SAN JACINTO
HEMET
Lake Elsinore
Bear Lake
Lake Hemet

CHAPTER II

GENERAL SITUATION ON SANTA ANA RIVER AND TRIBUTARIES

In Bulletin 19, "Santa Ana Investigation," which reported on the work of the Division of Water Resources, State Department of Public Works, up to and including 1928, it was stated:

> The tributaries west of Lytle Creek, except in the most violent floods, sink into the gravels before they reach the river. Consequently, channels are not maintained across the lower Cucamonga Basin. Property damage results when the extraordinary flood carves new channels and forces its way to the river. The method of control will be to increase percolation by proper spreading works, located where property improvements are small, thus dissipating the water in the same way that nature now does in the gravel cones, supplemented by channels where necessary to carry the excess to the river. Cost of reservoirs in these tributaries precludes recourse to them. Ultimate extent of spreading works will be dictated by experience. The tributaries east of Lytle Creek have the same characteristics as those west, but there is less waste land, property improvements are much greater and distance to the river is less. Spreading works here also are indicated but these may have to be supplemented by channels to the river.
>
> The larger tributaries present a different problem. The discharge of Lytle Creek is large, and property through which it flows has high value. Hazard to life exists in Colton. A reservoir of 5000 acre-feet capacity may be built in Turk Basin, which will reduce floods about 2500 second-feet and enable them to be spread in the channel and on the east side to an extent or diverted to the Rialto area, or they may go to the river direct through an improved channel. Both San Timoteo Creek and Temescal Creek are susceptible of reservoir control, but possible property damage is not large and channel improvement would almost eliminate it. On Santiago Creek a reservoir of 24,000 acre-feet capacity at upper or lower sites would reduce the capital flood to 2300 second-feet through the city, which capacity could be provided by almost negligible channel improvement. All control on tributaries by spreading or properly designed flood control reservoirs contribute to reduction of flood hazard on the river itself. The greatest possible damage is from the river.
>
> From the physical standpoint the most obvious combination on the river is (1) reservoirs in Santa Ana Canyon and Mill Creek in the mountains, but near the debouchure into the valley, (2) superspreading on the cone, (3) channel improvement and protection works in the migratory section from above San Bernardino to a point opposite Colton, (4) a reservoir in lower Santa Ana Canyon and (5) channel improvement from the canyon to the ocean. Such a combination would give regulation above each dangerous reach of the river and above each spreading ground, and an improved and confined channel below. It would also function well from the standpoint of conservation because of the large areas of irrigated land below each reservoir. The separate units which comprise the foregoing combination in Santa Ana Valley should receive careful consideration of cost, as compared to benefit, before adoption.

It will be noted that no recommendations are made in the above. The intent of Bulletin 19 was to set out the salient facts and conclusions about each feature susceptible of being used in flood control and conservation of Santa Ana Basin water. The more important features are mentioned in the above paragraphs.

The legislature of 1929 appropriated funds for further study of the water resources of Santa Ana Basin. As Orange County formed a district in 1927 for the purpose of flood control and conservation of all waters wasting in Orange County and as the program at first laid down is being exhaustively restudied by a board of engineers retained by the district, whose recommendations are expected in the not distant future, the work of the state has been confined to the Upper Santa Ana Basin or Valley. Statements hereinafter made in regard to hydrological features of conservation and flood control at and below Lower Santa Ana Canyon are based on Bulletin 19, above mentioned and also on data contained in a report by the former Chief Engineer of Orange County Flood Control District dated April, 1928. It should be realized that changes in the features discussed may be recommended by the board of engineers now retained by the district and that any program herein outlined for the lower river is tentative only.

Discussion is here limited to the Santa Ana River system which embraces the river and its tributaries. Santiago Creek is the only important tributary in the lower area. All of the other small streams in the Lower Basin reach the ocean through other channels.

Study of the situation reveals that a reservoir in Lower Santa Ana Canyon, or, as a substitute, a reservoir at the Jurupa site on the river above the canyon and between Corona and Riverside, possibly with auxiliary reservoirs on Temescal and Chino creeks, is necessary for flood control below the canyon, and also that such a reservoir is necessary for complete conservation of the waters of Santa Ana River. As estimated in Bulletin 19 the average waste during floods originating above the canyon has been 26,000 acre-feet per year during the thirty-four years dating back from the season of 1927–28. The Chief Engineer of Orange County Flood Control District estimated that a reservoir of 180,000 acre-foot capacity is necessary to reduce the capital flood to 6000 second-feet past the city of Santa Ana. He also estimated such a reservoir would conserve 97 per cent of the long-time average annual discharge in the canyon, which is estimated to average 148,000 acre-feet annually. Three per cent of this is 4400 acre-feet, which represents the average annual loss with the reservoir constructed. It should be stated that most of the 148,000 acre-feet is rising water, naturally regulated and fully used below. Assuming that the above estimated waste of 26,000 acre-feet represents a quantity which may be called the average waste, the salvage by means of this reservoir would be 21,600 acre-feet, or in round figures 22,000 acre-feet, per year. In other words, about 83 per cent of the long-time average flood waste from above Lower Santa Ana Canyon would be salvaged without other works. The present report deals only with the past thirty-six years and for that period it is estimated this reservoir would have salvaged an annual average of 23,000 acre-feet.

The annual flow of the Santa Ana system is widely erratic. Features in the Upper Valley which would conserve water would be so expensive and so small in comparison with the run-off of the larger floods that whatever can be done toward salvage and control in the Upper Valley would have little effect on the amount of water reaching the Lower Canyon in these floods. Consequently, if the waters of the stream are to be salvaged and if flood control in the Lower Basin is to be accomplished in this way, a reservoir on the lower river is necessary and its capacity will be dictated by the requirements for control of the capital flood. This would give excess capacity in the years of more moderate floods.

In a few words, this is the key structure for flood control in the lower river. It would conserve practically all the water now wasting from the Upper Valley. Flood control also is necessary in the Upper Valley independent of the needs of the Lower Basin. Additional water supplies also are needed above. and while a reservoir in the Lower Canyon would conserve practically the entire waste it would make water available for use only in the Lower Basin.

As before stated, possibilities in the Upper Valley for conserving more than a small part of the large floods do not exist. Estimates indicate that even at the Filirea reservoir site, which is the cheapest in the headwaters and which would be utilized only for smoothing out peaks so that additional water could be conserved by causing it to sink underground on Santa Ana River cone near the mountains, the capital cost for the reservoir alone would approximate $670 per acre-foot of average annual yield of only 2400 acre-feet.

There are, however, possibilities in the Upper Basin for conserving, at reasonable cost, a considerable portion of the waste of the average years. This water would be available there. Such conservation works also would aid in flood control in the Upper Valley, but, as stated before, these works would not reduce the storage capacity necessary in the lower river for control. If the upper works are constructed, most of the run-off in the floods of high years and portions of the floods of the years of average run-off will reach the Lower Canyon, while varying amounts would be conserved in the Upper Valley.

Conservation in the entire Santa Ana Basin is dependent on utilization of underground storage. This is particularly true of the Upper Valley where feasible surface reservoirs are almost nonexistent. Most of the streams of the Upper Valley have cones of such magnitude and of such porous character that spreading works which will act as detention reservoirs can be constructed and thus smooth out peaks and greatly increase percolation. In themselves, these would reduce the flood hazard in the Upper Valley materially. Spreading can be done on the gravel beds in the mountains and these beds can be pumped after flood season and the water conveyed to the valley. Small dams, which may be called debris dams, can be constructed to store small amounts of water, hold back debris from the valley and create new gravel beds. Flood control in Upper Santa Ana Valley encounters the problem of debris disposal and such dams, in addition to conservation features, would aid in this.

As a whole the entire program of flood control and conservation in the Upper Valley is one of numerous small features. In the Lower Basin it is a matter of a few large features.

The fact that the program in the Upper Valley is one of small features fits in well with a plan of progressive development desirable there. The art of constructing spreading works is not yet fully developed. Enough has been done to indicate its possibilities and its limitations. Such works as are proposed as a result of this study are unprecedented in magnitude. Each should be conservatively and progressively built so that results can be observed and changes made as indicated. This is true also of the construction of the barrier dams proposed in the mountains. One near the canyon mouth would prevent debris from reaching the valley until it is filled. Then another could be built. Likewise, development of underground reservoirs in the mountains should proceed slowly.

The program in the Lower Basin would consist principally of constructing a few large reservoirs and channel control. Construction of a reservoir once started should proceed rapidly to completion.

Water Rights.

This report does not deal with the question of water rights. Due to the complex legal and physical situation on the Santa Ana, practically nothing can be done without furnishing ground for an attack based on one kind of water right or another. Unless these matters are settled, either by tacit consent or by formal agreement, the work will be delayed or may be stopped. This calls for practically complete agreement on the part of water users below any works proposed for any conservation program.

As to this matter it may be said that the works proposed herein for the Upper Valley are in regions from whence comes, as estimated in Bulletin 19, about 50 per cent of the waste into the ocean through Santa Ana channel, but it is believed they would not retain more than half of this 50 per cent. In other words, it is thought that not more than 25 per cent of the average flood waste can be thus retained in the Upper Valley. The percentage in high years would be much less. This estimate is, of course, based on very insufficient data and does not pretend to be more than a rough approximation.

CHAPTER III

WEST END OR CHINO BASIN SYSTEM

The group of tributaries on the west side of Upper Santa Ana Valley and west of Lytle Creek discharge into the Chino Creek trough and thence into Santa Ana River. Each has created its separate cone on which spreading may be accomplished and which requires its own flood control works. Below the cones, stream channels become more or less indistinct because only during the more severe floods does water flow across the basin to the river. Protection from flood damage requires adequate channels from the cones to the river. It was found that all the streams, except San Antonio Creek, could best be concentrated in one channel leading to a deep draw flowing direct to the river instead of into Chino Creek. As the works for San Antonio Creek are planned, the stream would follow its present channel to Chino Creek.

The general map of Santa Ana Basin shown in Plate II gives the location of the various works herein discussed. In the following pages the detail of works on the different tributaries and the main stream are discussed.

San Antonio Creek.*

San Antonio Creek, while subject to floods, has a better sustained flow than the creeks to the east because it comes from a higher and more retentive drainage area. The salient facts pertaining to the watershed are:

Drainage area	25.0	square miles
Average annual discharge	16,600	acre-feet
Peak flood flow used in design of flood channel	10,000	cubic feet per second

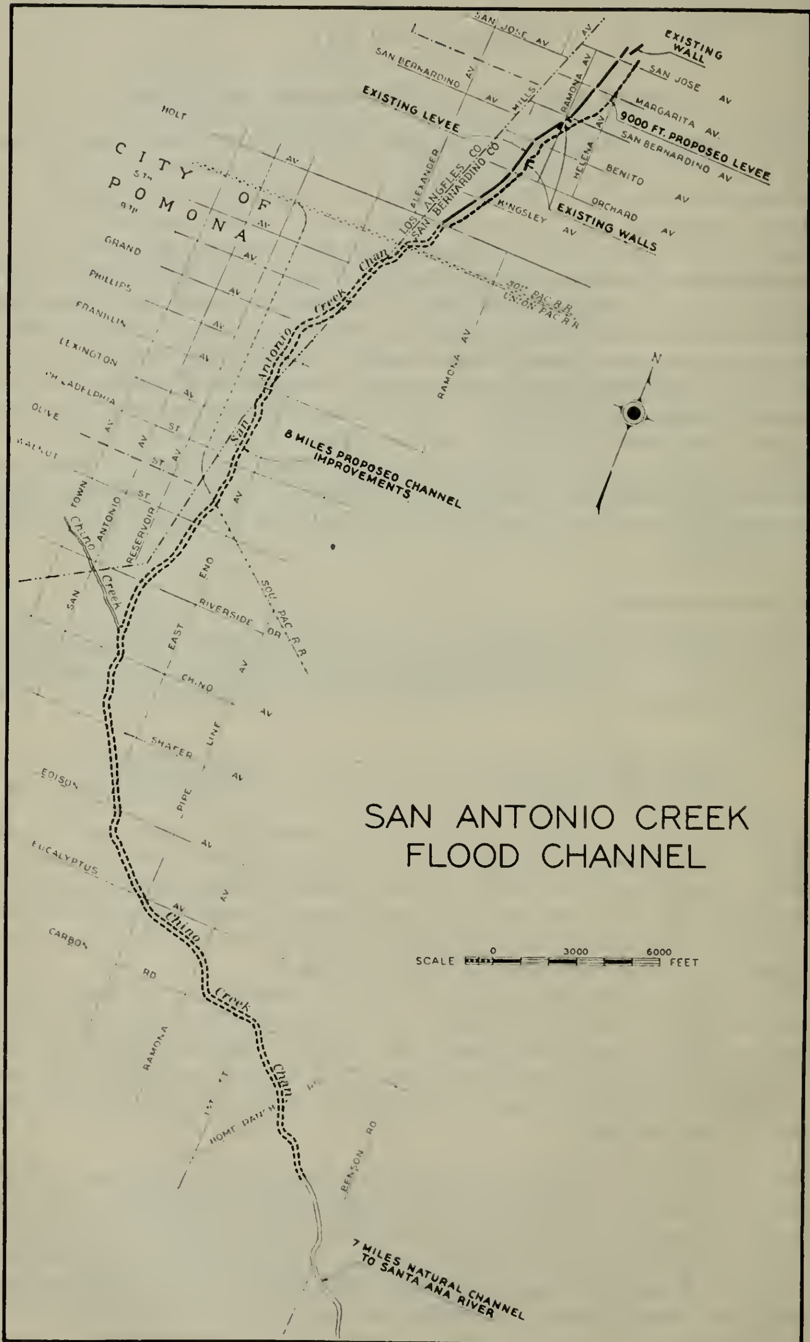
Spreading works.—These are now well developed on San Antonio Creek. Los Angeles County Flood Control District has constructed works to cover the entire west side below the diversion works constructed some years ago. On the east side the Pomona Conservation Association is constructing additional spreading works and when these are completed all the available area will be covered.

The best data available indicate that 350 second-feet of water were absorbed during the 1927 flood. It is thought by engineers of the district that at least 500 second-feet can be absorbed when the new works on the east side are completed. All of this work is being done by local organizations and no additional spreading works are proposed in this report.

Channel protection.—San Antonio Creek forms the approximate boundary between Los Angeles and San Bernardino counties, and Los Angeles County Flood Control District has constructed protection works along the west side to Holt avenue. The creek leaves Los Angeles County at Franklin avenue and flows entirely on the San Bernardino side of the county line. Protection on the east side is required from

* See Plate III.

PLATE III


SAN ANTONIO CREEK
FLOOD CHANNEL
CITY OF POMONA
EXISTING WALL
EXISTING LEVEE
EXISTING WALLS
9000 FT. PROPOSED LEVEE
8 MILES PROPOSED CHANNEL IMPROVEMENTS
7 MILES NATURAL CHANNEL TO SANTA ANA RIVER
San Antonio Creek Chan.
Chino Creek
Chino Creek Chan.
LOS ANGELES CO.
SAN BERNARDINO CO.
SOU. PAC. R.R.
UNION PAC. R.R.
SAN JOSE AV
SAN BERNARDINO AV
MARGARITA AV
BENITO
ORCHARD
KINGSLEY AV
HOLT
GRAND
PHILLIPS
FRANKLIN
LEXINGTON
OLIVE
RESERVOIR
RIVERSIDE DR
CHINO
SHAFER
EDISON
EUCALYPTUS
CARBON
RAMONA AV
BENSON RD
N
SCALE 0 3000 6000 FEET

Holt avenue north about 9000 feet. Below Holt avenue the channel should be improved for a distance of eight miles to the point where it enters the narrow valley of Lower Chino Creek, which is separated from the main valley by a range of low hills. Of the eight miles, three and eight tenths miles are on San Antonio Creek and the remainder on Chino Creek. Damage which might occur for the next seven miles to the Santa Ana River does not warrant protection works. The grade in this portion is flat and the soil is of a heavy character which does not wash. The greatest possible damage would be the flooding by slowly moving water of a few fields not planted in high quality crops. Of the eight miles which should be improved there are one and five tenths miles that require very little excavation as, in most places, the channel has ample capacity to carry the 10,000 second-foot estimated peak flood. On the remaining six and one half miles there are already levees, but these should be increased in size and one moved back to give required capacity. A right of way 300 feet wide is assumed.

The estimated cost of these works, given in detail on page 53, aggregates $317,500.

Cucamonga Creek.

Drainage area	10.3 square miles
Estimated peak flood flow	4,000 cubic feet per second

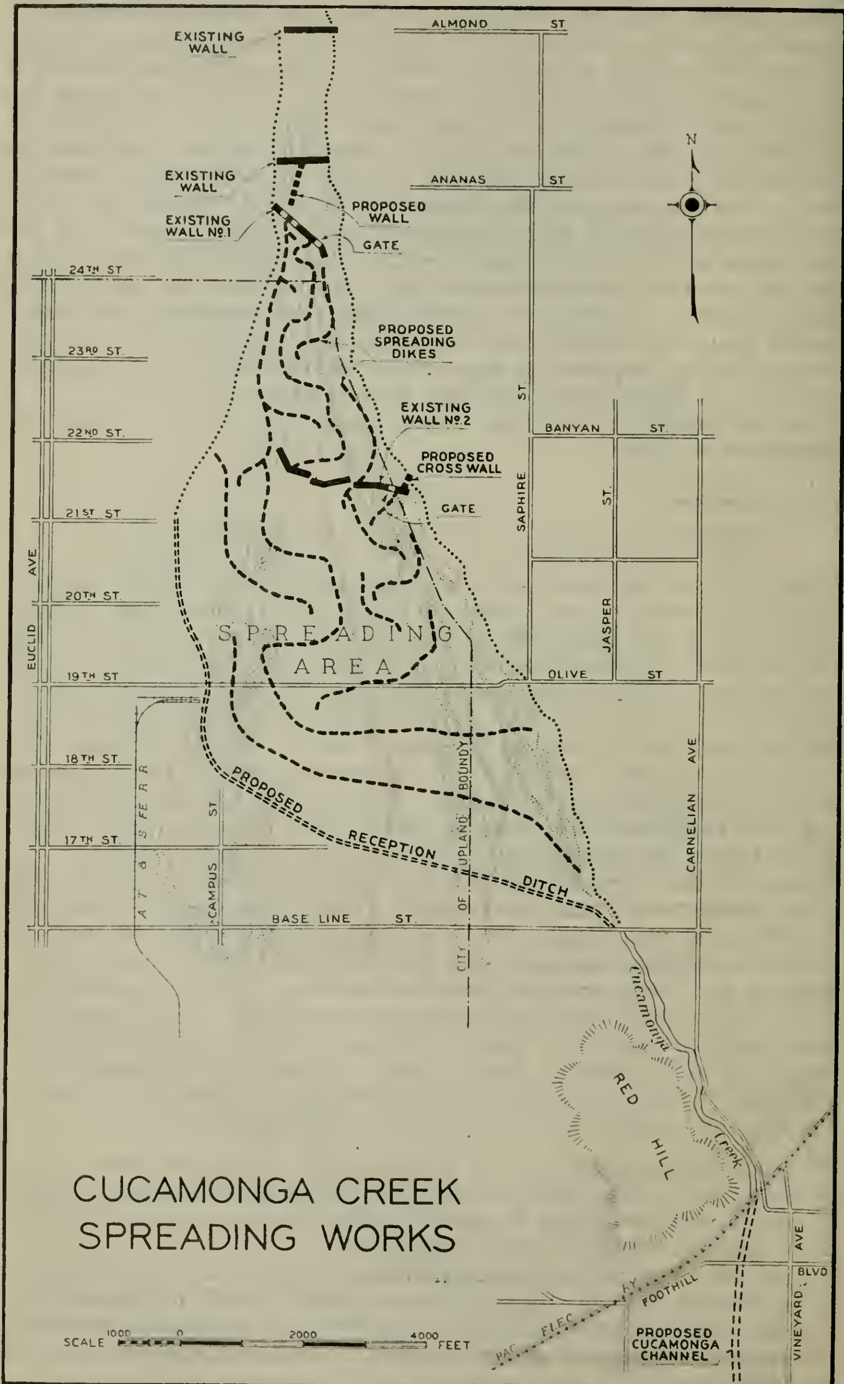
Existing spreading works.—At the debouchure from the mountains, Cucamonga Creek enters a deep cut in the debris cone. This is about 900 feet wide and about 100 feet in depth at the deepest point. The cut gradually becomes shallower as it proceeds from the mountains and at a point about a mile and a half from the mountains the stream begins to bifurcate and may follow one of several channels. About $40,000 has been expended by San Antonio Water Company and Cucamonga Water Company in constructing weirs for spreading water in the bottom of the channel. This construction consists of rock and wire walls across the channel. The upper two are at right angles to the axis of the stream and are approximately 2200 feet apart. At a point 700 feet downstream from the lower wall another extends diagonally downstream from the west bank. This is equipped with gates and cross walls at right angles to the wall immediately below the gates to aid diversion for spreading. At a point 4000 feet downstream from the diagonal wall there are three walls across three different channels and running diagonally downstream from the west bank. These spread the water and also divert it toward the east channel, through which it passes out of Cucamonga Basin. San Antonio Water Company owns 885 acres at the lower end of the cone which is adapted to spreading. The slope of the cone at this point varies from 2 to 5 per cent.

*Proposed spreading works.**—It is proposed to utilize the present works in a plan to cover the entire 885 acres owned by the San Antonio Water Company with structures to enable the floods to be spread. The ultimate capacity would be 4000 second-feet.

Only the principal levees and diversion features have been planned. It is believed that by these structures floods would be divided into streams which could be handled with safety, but it would be necessary to construct a large number of small weirs and dams between the

* See Plate IV.

PLATE IV


EXISTING WALL
ALMOND ST
EXISTING WALL
ANANAS ST
EXISTING WALL Nº 1
PROPOSED WALL
GATE
N
24TH ST
23RD ST
PROPOSED SPREADING DIKES
22ND ST
EXISTING WALL Nº 2
BANYAN ST
PROPOSED CROSS WALL
GATE
21ST ST
SAPHIRE ST
ST
EUCLID AVE
20TH ST
JASPER
SPREADING AREA
19TH ST
OLIVE ST
18TH ST
A T & S FE R R
CAMPUS ST
PROPOSED RECEPTION DITCH
17TH ST
CITY OF UPLAND BOUNDY
CARNELIAN AVE
BASE LINE ST
Cucamonga Creek
RED HILL
CUCAMONGA CREEK SPREADING WORKS
AVE
BLVD
FOOTHILL
VINEYARD
PAC. E.L.E.C. RY.
PROPOSED CUCAMONGA CHANNEL
SCALE 1000 0 2000 4000 FEET

planned levees in order to keep the water spread. Experiments on the absorptive capacity of this cone give rates as high as nine inches per hour in depth, which is very high. The spreading works would increase the time of travel of water across the cone and by reason of this, and also by reason of the absorption in transit, it is believed the peak of the capital flood could be materially reduced and that ordinary floods could be entirely absorbed. It is not believed that the entire spreading works should be constructed at one time, but rather that one of the three units should be constructed first and results observed. This would require reconstruction of the diversion weir and also construction of such parts of the gathering channel on the lower side as is necessary.

The spreading works and channel may be likened to a detention reservoir with a spillway.

Debris from the floods would be deposited in the spreading works when the amount of water is not sufficient to carry it entirely through. This would tend to decrease the percolation factor and it is assumed it would be necessary to break this up mechanically at frequent intervals.

The long diagonal wall mentioned above would be strengthened and raised an average of 2.5 feet as shown in Plate XIV. Three batteries of gates with capacity of 1000 second-feet each would be installed in the wall. Each battery would have a clear opening of 48 feet in units four feet wide. Stop planks would be used to regulate the flow as indicated in Plate XII. On the upstream side of the wall, at right angles to it and just below each battery of gates, a small rubble wall would be built as shown in Plate XIV to protect the bottom from erosion. Surplus water not diverted through the gates would pass around the lower end of the wall and follow the east channel for 4000 feet where another wall would divert it to the west.

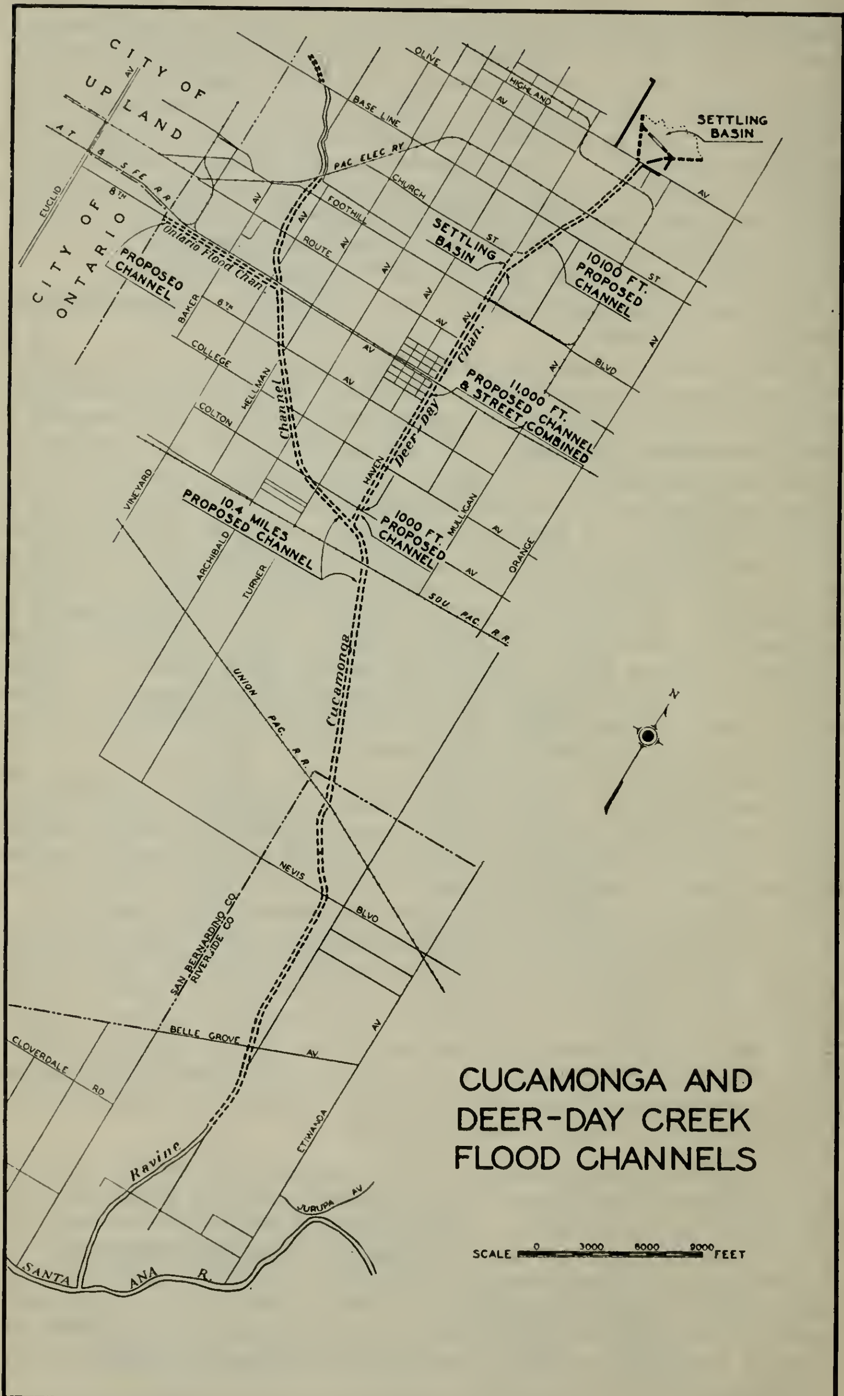
The maximum flood would thus be separated into four streams of 1000 second-feet each. These would be kept separated by low unlined levees with ten feet top width, two to one, and three to one side slopes and an average height of about eight feet, which would direct the water back and forth across the cone, reduce the grade to about one per cent and the velocity for 1000 second-feet to about seven feet per second.

At the lower end of the spreading ground and on its west and south sides a ditch with capacity of 5000 second-feet would be constructed. A cross section is shown on Plate XI. This additional capacity would be provided to care for storm water originating on the valley floor. This ditch would be broad and flat and the excavation would be deposited on the downstream side to intercept the surplus from the spreading grounds and return it to the east channel at the Base Line road crossing. The channel also would be improved below.

*Proposed channel improvements.**—The channel flows on the east side of Red Hill and improvement is not necessary until the Pacific Electric Railroad crossing is reached. At this point a channel with a capacity of 5000 second-feet is proposed. It would follow the present wash to a point near Hellman avenue crossing and would then deflect to the east, passing near the intersection of Turner and Colton avenues, and crossing the Union Pacific Railroad about two miles west of Wineville where it would enter a swale running in a southerly direction to the

* See Plate V.

PLATE V


CITY OF UPLAND
CITY OF ONTARIO
SETTLING BASIN
SETTLING BASIN
10100 FT. PROPOSED CHANNEL
PROPOSED CHANNEL
11,000 FT. PROPOSED CHANNEL & STREET COMBINED
1000 FT. PROPOSED CHANNEL
10.4 MILES PROPOSED CHANNEL
Ontario Flood Chan.
Deer-Day Chan.
Cucamonga Channel
PAC. ELEC. RY.
A.T. & S.FE R.R.
SOU. PAC. R.R.
UNION PAC. R.R.
SAN BERNARDINO CO.
RIVERSIDE CO.
BASE LINE
CHURCH
FOOTHILL
ROUTE
COLLEGE
COLTON
NEVIS BLVD
BELLE GROVE AV
CLOVERDALE RD
JURUPA AV
SANTA ANA R.
Ravine
EUCLID
BAKER
HELLMAN
VINEYARD
ARCHIBALD
TURNER
HAVEN
MULLIKAN
ORANGE
ETIWANDA
OLIVE
HIGHLAND
N
CUCAMONGA AND DEER-DAY CREEK FLOOD CHANNELS
SCALE 0 3000 6000 9000 FEET

river. At the junction with the channel from Deer and Day creeks, which is approximately one mile below Hellman avenue crossing, the capacity would be increased to 6000 second-feet. Practically any capacity is possible by widening the space between dikes which can be done without changing the cost. Improvement is not necessary through the swale. The dikes proposed for construction are shown on Plate XI.

A lateral 7500 feet long and with a capacity of 750 second-feet is proposed from the east boundary of Ontario along Eighth street to a connection with Cucamonga flood channel to provide an outlet for the run-off from the streets of Upland, Upper Ontario and the territory to the east of Upland. With this relief it is believed the run-off from Ontario below Eighth street can be taken care of in the natural channels south of Ontario.

A right of way 200 feet wide should be obtained for the main channel to provide for disposal of debris entering the channel. The right of way for the lateral to Ontario is assumed to be 75 feet in width.

Standard plans of Division of Highways are proposed for culverts under major highways. Lateral highways would be dipped to cross the channel.

The estimated cost given in detail on pages 54, 56 and 58 totals \$781,600, including \$241,400 for spreading works and \$540,200 for channel improvements.

Deer and Day Creeks.

Drainage Area	
Deer Creek	3.5 square miles
Day Creek	4.9 square miles
Miscellaneous	2.3 square miles
Total	10.7 square miles

Estimated peak discharge, 4000 cubic feet per second.

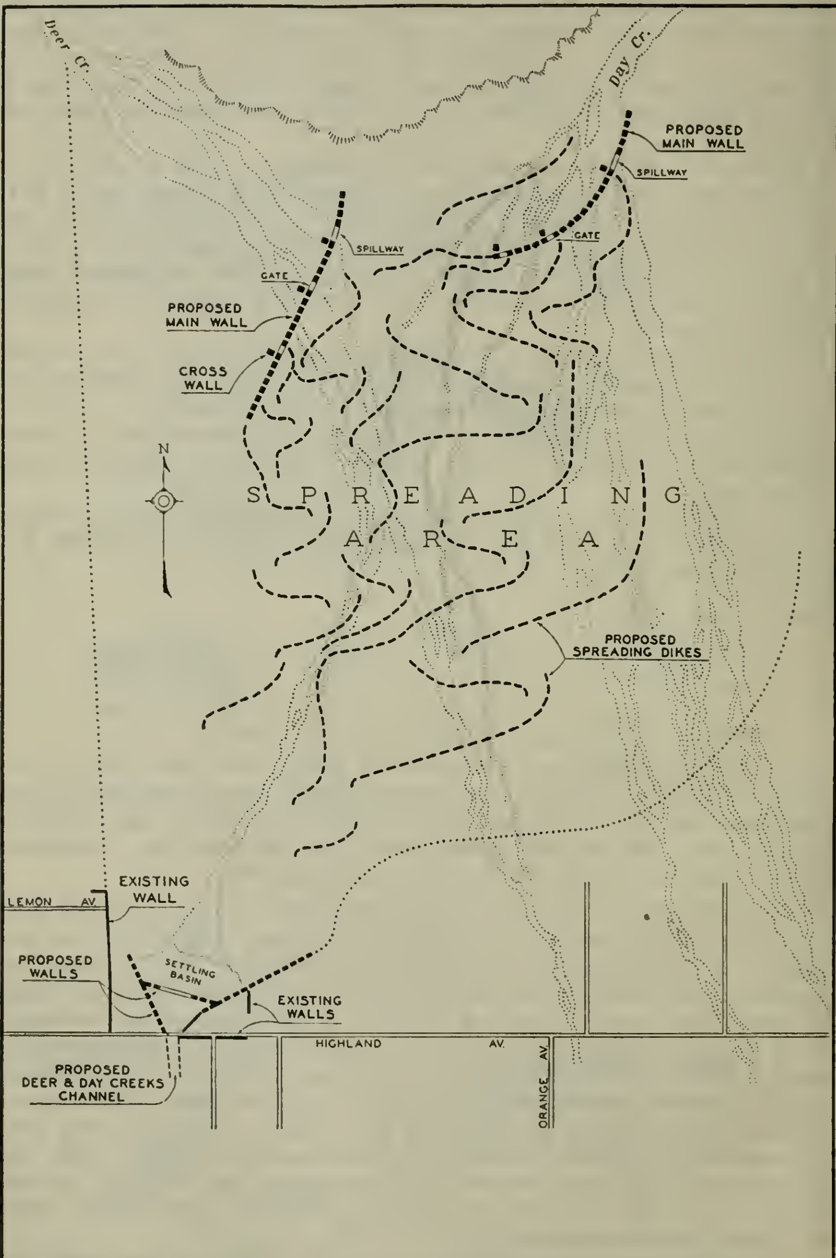
Deer Creek, which lies to the west of Day Creek, has built a very high cone and at present its waters are flowing on the east side of the cone along the foot of the mountains. Day Creek also has built an extensive cone and its waters are flowing on the west side. Between the two cones is a trough where the two streams join.

*Spreading works.**—Levees are ultimately to be built to insure the continued flow of the creeks on the sides of the cones where they now are flowing. In each stream, before reaching the bottom of the trough between the two cones, a levee would be built to carry the water out onto the respective cones. In each a spillway of 2000 second-feet capacity would be placed at the point where the main stream comes against the levee, as shown in Plate XII. The water thus spilled would be diverted again at a lower point with a similar levee. After being diverted onto the cone, various levees would carry the streams diagonally back and forth across the east and west sides of the cones, respectively. Only the major works have been planned and to increase the efficiency of the spreading grounds it would be necessary to place many small dams and levees.

At a point just north of Highland avenue all the water would be collected by two levees, which would approach each other funnelwise and bring the water to a spillway of 4000 second-feet. This would serve as a catch basin.

* See Plate VI.

PLATE VI



DEER & DAY CREEKS SPREADING WORKS

The area which may be used for spreading works is 1900 acres and it would seem possible to so construct the details of the spreading works that practically any flood could be absorbed without a channel to carry away the surplus. However, in view of the fact that the capacity for percolation in the spreading works is not known, a channel is proposed below the spillway. Levees would be of the cross-section shown on Plate XI and with a height of ten feet.

Channel.—From the spillway above described the water would follow the present channel to Haven avenue crossing. The present channel would be made wider and deeper with unlined levees along both sides having a cross-section as shown on Plate XI.

Above Haven avenue another catch basin for sand is proposed. Haven avenue would be paved and curbs constructed four feet high to form a conduit to Colton avenue where an earth channel of 4000 second-feet capacity would be constructed to carry the water 1000 feet to a connection with the Cucamonga flood channel previously described. This channel would have levees of the same section as above described and 200 feet right of way is recommended.

The estimated cost of this project, set forth in detail on pages 55 and 57, is $568,200. Of this sum, $339,700 is for spreading works and $228,500 for channel improvements.

CHAPTER IV

LYTLE CREEK SYSTEM

Drainage Area

Lytle Creek	39 square miles
Cajon Creek	42 square miles
Total	81 square miles

Estimated peak discharge, 25,000 cubic feet per second.

Lytle Creek has somewhat more favorable reservoir sites than the creeks on the west end or Chino Basin. Investigations have disclosed three sites:

Turk Basin reservoir site.
Meyers reservoir site in the canyon of Meyers Creek.
Keenbrook reservoir site on Cajon Creek near its junction with Lone Pine Creek.

The Turk Basin site is capable of improvement with a 155-foot dam, which would give a capacity of 5000 acre-feet and which can be constructed at an estimated cost of $3,970,000 for a gravity type concrete structure.

Meyers Creek does not discharge sufficiently to justify a reservoir to store the flow of that stream but water can be diverted to it from Turk Basin by tunnel. With this added supply, the site is capable of being developed to 5000 acre-foot capacity with a 157-foot gravity type concrete dam, which would cost $2,000,000.

The Keenbrook reservoir could be developed to 16,600 acre-foot capacity through construction of an 180-foot concrete dam at an estimated cost of $5,400,000.

The escape from Lytle Creek into Santa Ana River is on the average small, and neither for flood control nor for conservation are these reservoirs justified. The average yield would be far less than the above capacities.

Cajon Creek has a flashy flow, but also has a very broad expanse of sandy bed along which most of the stream sinks and is conserved, except in the capital flood. Lytle Creek itself is not so well favored and construction of spreading works is advisable. While parts of such works would aid in flood control, bank protection also would be required for that purpose along the west side and an improved channel would be required from the vicinity of Foothill boulevard to the junction with Santa Ana River to protect life and property in San Bernardino and Colton.

The Lytle Creek Water Users Association has constructed a weir 1941 feet long across Lytle Creek wash a short distance below its debouchure from the mountains. At the east end water is diverted to a mesa containing about 1000 acres of excellent spreading grounds. Construction of the weir has caused the bottom of the channel to fill upstream from it and there is danger that the stream will break out on the west side and go into the highly cultivated area around Rialto.

Works Planned.

Lytle Creek flows on the east side of a broad flat cone at present. It is in a more unstable state of equilibrium than the other streams of the Santa Ana Basin. When it has built up its bed its next move will be to the west and revetment works are necessary to delay this natural movement. Diversion works already constructed increase the danger of this movement of the stream to the west.

*Proposed spreading works.**—Diversion to spreading works proposed, and on which cost estimates are based, would utilize 450 feet of the east end of the present dam as a spillway. This would be strengthened, and on the extreme east end a roller gate 50 feet long would be installed. The gate would be so arranged that it could be raised out of the way of floods and, when raised, allow the stream to scour in front of the diversion weir. A diversion weir with manually operated gates would be built at right angles to the spillway to take 2000 second-feet to the spreading grounds on the east. The crest of the spillway under the roller gate would be five feet below the sill of the diversion weir in order to allow flushing of the sand.

Beginning at the hills on the west side, a dike twelve feet high, with cross-section of three to one on stream side and two to one on land side and with a ten-foot top width, lined with gunite and rubble and with a flexible apron 20 feet wide, would run diagonally southeastward to the present weir on the west end of the part to be reinforced. This would cause all water to flow toward the east end of the weir and diversion would be regulated by the spillway and the diversion works. From the diversion weir a channel of 2000 second-foot capacity would be constructed eastward to a natural channel flowing along the west side of the hills. In this four or more dams would be constructed to divert the water out to the west for spreading.

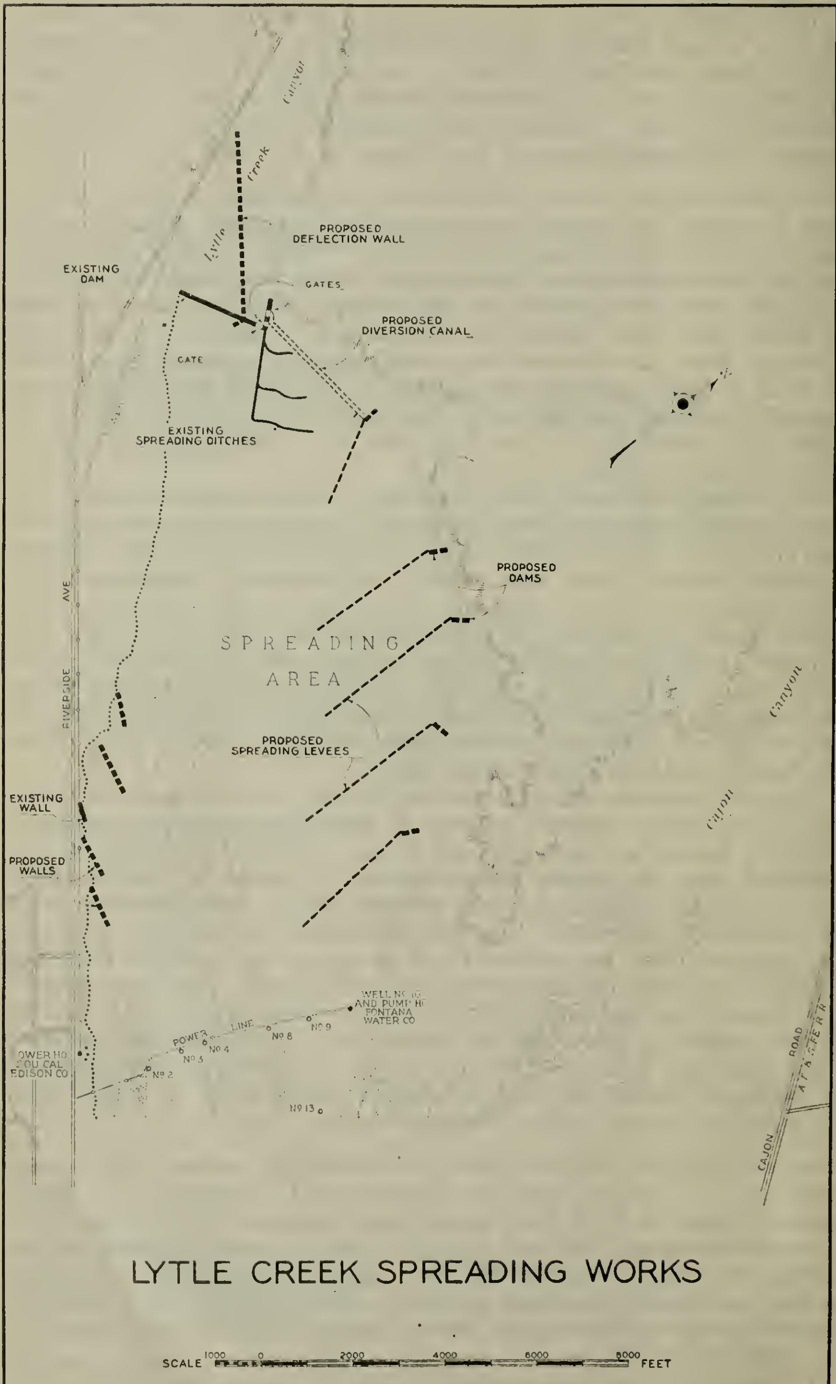
Here, as in the streams further to the west, only the major features have been outlined and the amount of water absorbed would be determined by numerous small dams and levees. This proposed construction. however, places the water under control. It would be inadvisable to build the entire spreading works at once, but one unit should be tried out and results observed. It would be necessary, however, to construct the diagonal levee, reconstruct the weir on the east end and construct the diversion works for utilization in the first unit. The small dams in the natural channel should be of the overflow type constructed of rubble masonry. Each unit as planned would handle 400 second-feet.

An alternate plan for diversion proposes a straight weir upstream at the lowest end of the canyon, where it would cause no hazard. and diversion by conduit to the spreading works.

*Revetment works.**—About 8000 feet below the present weir on the west side is a point of extreme weakness and protection is necessary for a distance of 4000 feet up and down stream. It is proposed to place deflecting walls of rock and wire there to cause the water to flow toward the center of the stream bed. Below this point the west bank is high and protection is not necessary. The deflecting wall would be approximately eight feet high, with a bottom width of eight feet and a top width of six feet.

* See Plate VII.

PLATE VII


Lytle Creek
Canyon
PROPOSED
DEFLECTION WALL
EXISTING
DAM
GATES
PROPOSED
DIVERSION CANAL
GATE
EXISTING
SPREADING DITCHES
PROPOSED
DAMS
SPREADING
AREA
RIVERSIDE AVE
PROPOSED
SPREADING LEVEES
EXISTING
WALL
PROPOSED
WALLS
Canyon
Cajon
WELL NO 10
AND PUMP HO
FONTANA
WATER CO
POWER LINE
NO 9
NO 8
NO 4
NO 3
NO 2
NO 13
POWER HO
SOU CAL
EDISON CO
ROAD
A T & S F R R
CAJON
LYTLE CREEK SPREADING WORKS
SCALE 1000 0 2000 4000 6000 8000 FEET

*Flood Channels.**—Below Foothill boulevard, Lytle Creek enters a well built up district and there is danger to life and property with present conditions. The old channel runs diagonally southeastward through the southwest corner of San Bernardino to Warm Creek, but at the present time the floods follow a central channel which goes directly through Colton. The east channel can easily be cleaned to carry 25,000 second-feet, but at its lower end it is probable it would have to be recleaned after each flood because the burden of sand would be deposited when the grade diminishes as the flow enters Warm Creek, which in turn takes it to Santa Ana River. It might be necessary to place a dike on each side in this section, but this could be considered an operating cost. A small amount of reconstruction of structures would be sufficient to carry 25,000 second-feet.

Reconstruction of the channel through Colton was considered, but it appears practically impossible to carry it on the direct route it occupies now. To divert it to the east above the intensively developed section of Colton would involve many structures under railroads and highways and it also would pass through a well settled area. A channel to the west was also surveyed. This would be entirely artificial and would carry the water along the mesa west of Colton and west of the Riverside Cement Works. Drops totaling 120 feet in height would be necessary and it would also be necessary to line the channel for its entire length in order to prevent cutting in the easily eroded sandy soils through which it would pass.

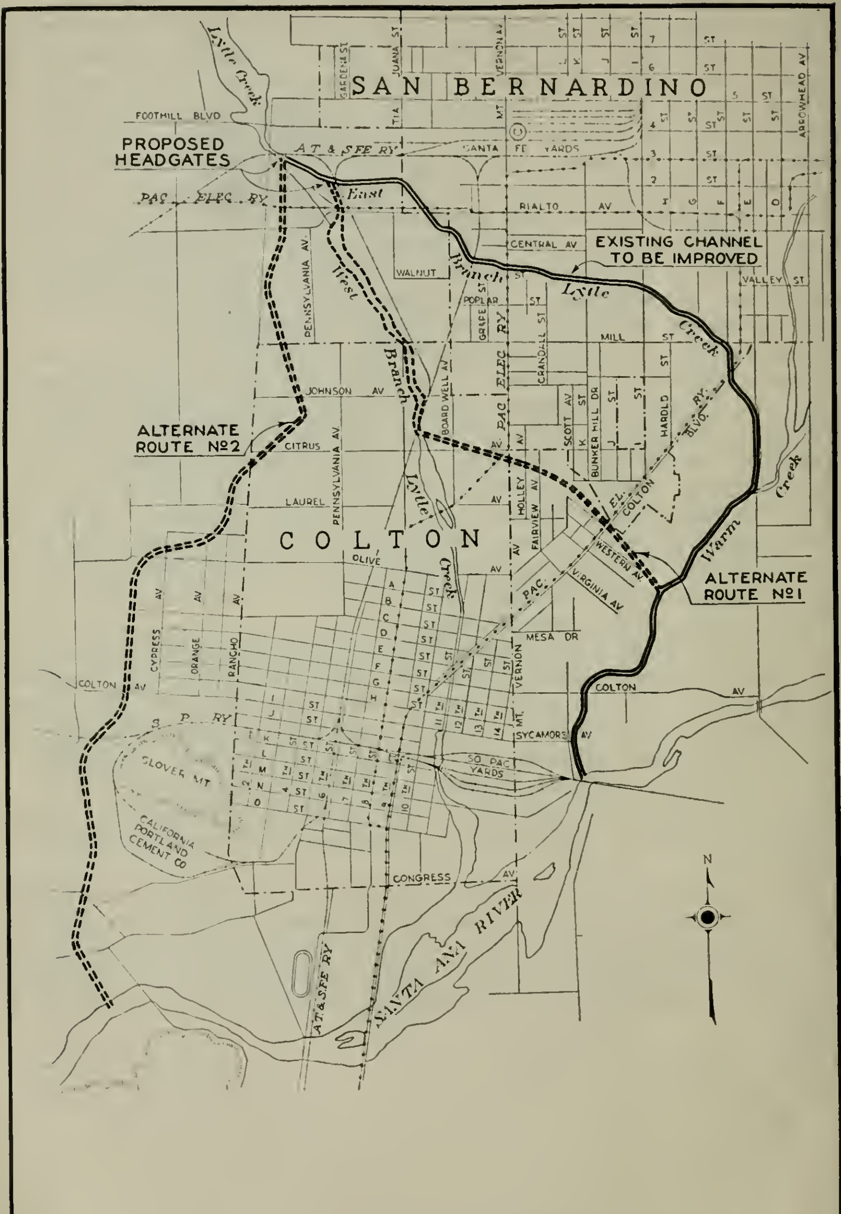
The east channel is recommended. At the junction of east channel with the present central channel it is proposed to install a concrete structure which would allow as much water to be diverted down the Colton channel as it could safely absorb in order to preserve the rights of such pumping developments as are found in that vicinity. Reconstruction of the bridge on Foothill boulevard would be necessary.

The estimated cost of this plan, given in detail on pages 59 and 60 is $635,500, involving $358,300 for spreading works and $277,200 for channel work.

This is considerably less than the cost of an alternate artificial channel on the west side, the estimated expense of that works being $1,367,800, details of which are set forth on page 62. The work on the present Colton channel alone under Alternate Plan No. 1 would involve an expenditure of approximately $583,300, as given in detail on page 61.

* See Plate VIII.

PLATE VIII



LYTLE CREEK FLOOD CHANNEL

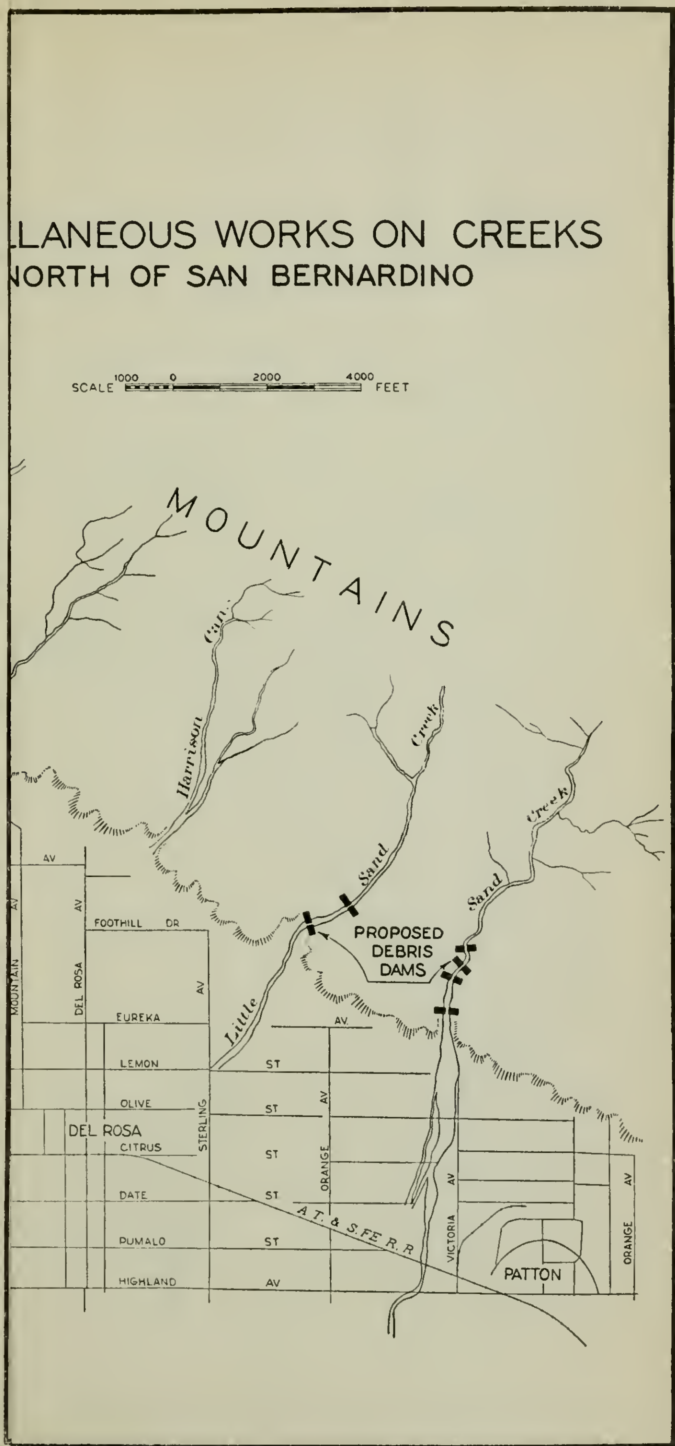
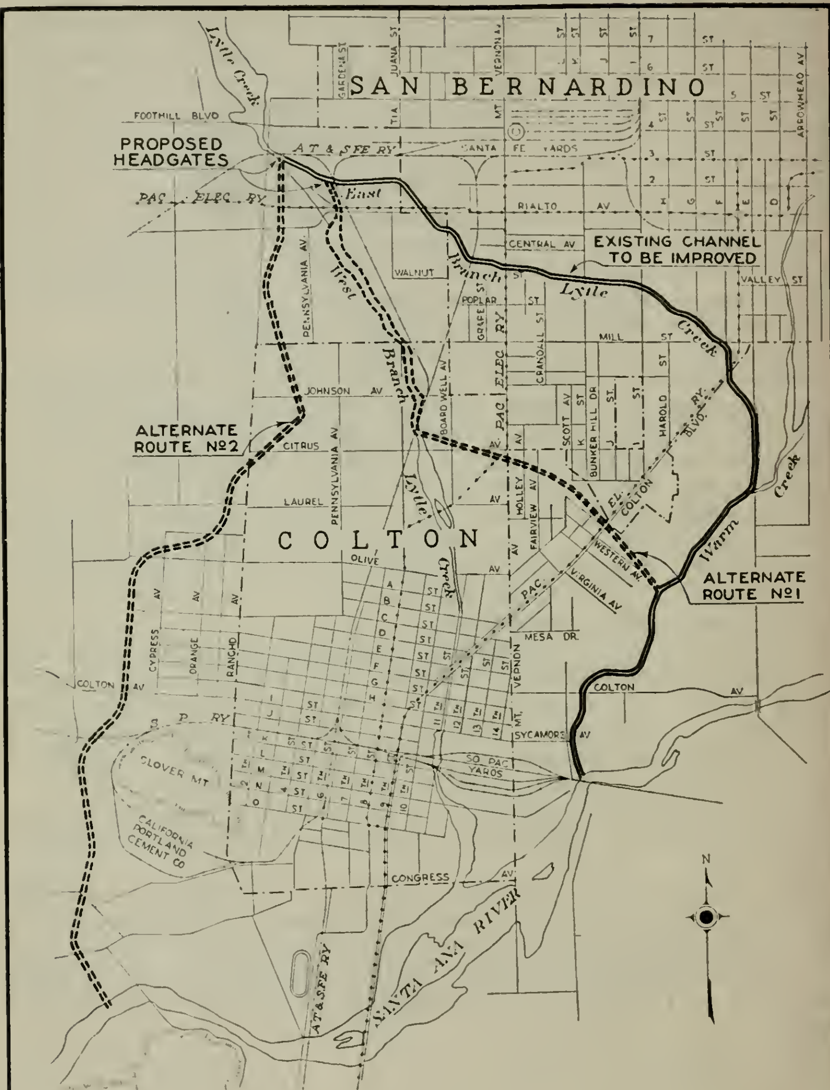
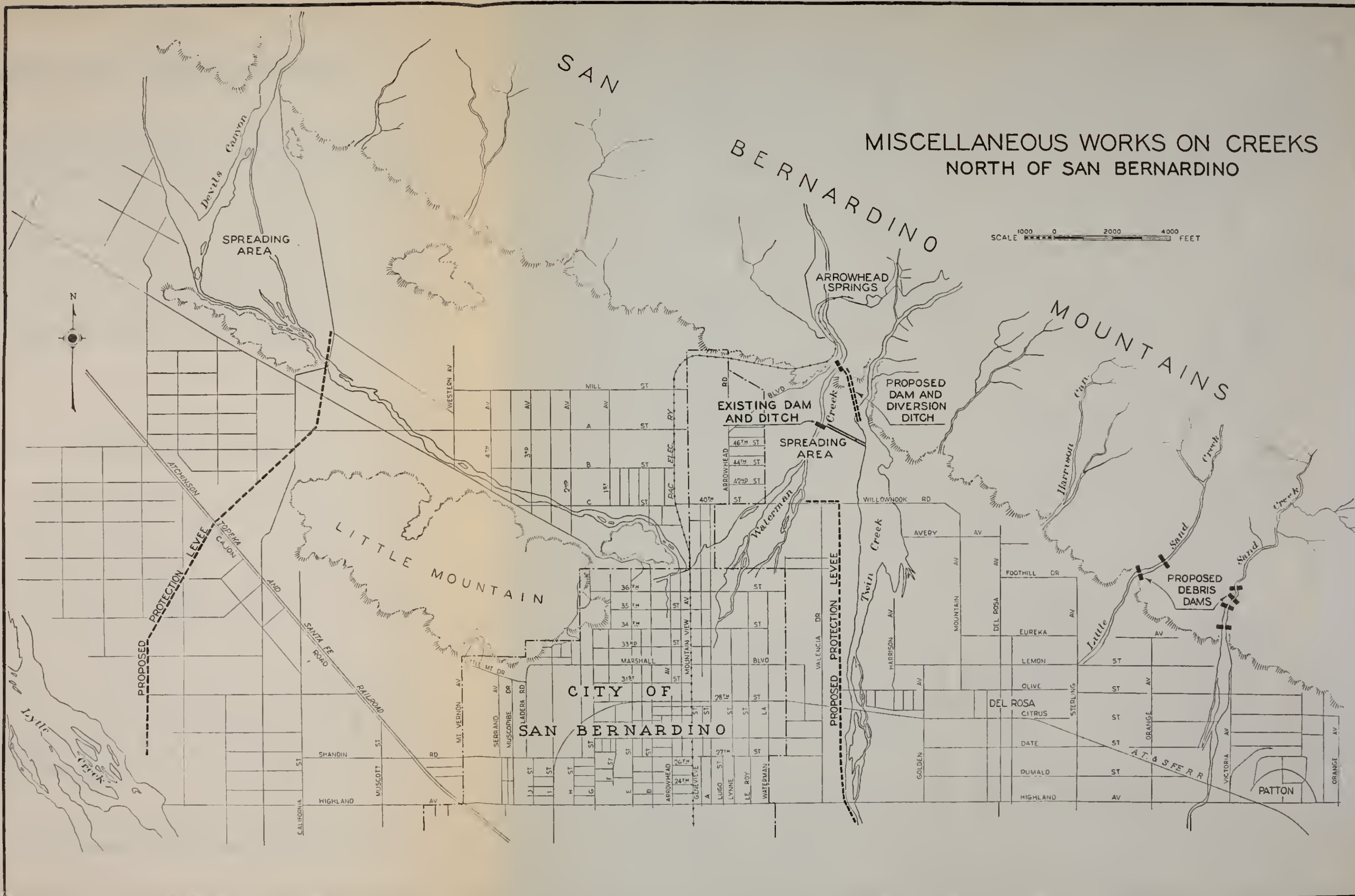

LLANEOUS WORKS ON CREEKS
NORTH OF SAN BERNARDINO
SCALE 1000 0 2000 4000 FEET
MOUNTAINS
Harrison
Can.
Creek
Sand
Little
Sand
Creek
PROPOSED
DEBRIS
DAMS
AV
MOUNTAIN AV
DEL ROSA AV
FOOTHILL DR
AV
EUREKA
AV.
LEMON ST
OLIVE ST
DEL ROSA
CITRUS ST
STERLING
ORANGE AV
DATE ST
PUMALO ST
HIGHLAND AV
A.T. & S.FE R.R.
VICTORIA AV
PATTON
ORANGE AV

PLATE VIII



LYTLE CREEK FLOOD CHANNEL

SCALE 0 3000 6000 FEET


MISCELLANEOUS WORKS ON CREEKS
NORTH OF SAN BERNARDINO
SCALE 1000 0 2000 4000 FEET
SAN BERNARDINO MOUNTAINS
LITTLE MOUNTAIN
CITY OF SAN BERNARDINO
SPREADING AREA
Devils Canyon
ARROWHEAD SPRINGS
EXISTING DAM AND DITCH
PROPOSED DAM AND DIVERSION DITCH
SPREADING AREA
PROPOSED DEBRIS DAMS
PROPOSED PROTECTION LEVEE
PROPOSED PROTECTION LEVEE
ATCHISON TOPEKA AND SANTA FE RAILROAD
CAJON ROAD
Lytle Creek
Waterman Creek
Twin Creek
Harrison Can.
Little Sand Creek
Sand Creek
DEL ROSA
PATTON
AT & SF RR
N

CHAPTER V

MISCELLANEOUS CREEKS AND WORKS

Works Planned.

*Devil's Canyon.**—This is a tributary to Warm Creek, but it is proposed to make it a tributary to Lytle Creek. The stream coming from the mountains impinges against a range of hills and then flows southeastward along their base. At the east end of the hills it is possible to divert the water with a low dike which would carry it around the east end of the hills and westward to Lytle Creek. After passing around the end the water would flow in an unimproved area and the only protection work necessary under the plan would be a six-foot dike running in a general southwesterly direction to Cajon Creek. This would extend from a point 2200 feet east from Kendall drive to a point 1700 feet north of Highland avenue. The cross-section proposed would have a ten-foot top width, two to one side slopes and a height of ten feet. This would protect the city of San Bernardino from Devil's Canyon water and enable all detailed spreading work necessary above to be installed.

The estimated cost of this plan, given in detail on page 64 is $40,200.

*Waterman and East Twin Creek.**—The city of San Bernardino has installed spreading works to handle 40 second-feet of water from Waterman Canyon, but this gives little protection to the city from flood water.

It is proposed to make a cut through a small saddle between Waterman Canyon and East Twin Creek, using the excavated material to construct a dam across Waterman Canyon. This dam would have an outlet for water to the present spreading works. The channel would have a capacity of 2800 second-feet.

A levee is proposed to run east and west along Willow Nook avenue to join a levee running south along the east side of Valencia avenue to a point about 400 feet south of Highland avenue, whence the water would follow a natural channel to Warm Creek.

This project, given in detail on page 65, is estimated to cost $42,900.

*Sand Creek and Little Sand Creek.**—The damage liable from these streams is deposition of sand on orchards. To construct channels would tend only to fill Warm Creek channel with sand. Therefore, it is proposed to construct concrete barriers from bedrock to the present stream bed surface near the mouths of the canyons and to construct retarding dams of driven pipe, tied together, filled with brush, and backfilled with sand.

This phase of the project is estimated to cost $45,800. Details are given on page 66.

City Creek.†—It is proposed to divert City Creek into the Santa Ana River at a point approximately 3500 feet west of Orange street.

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* See Plate IX.

† See Plate X.

This would require 3400 feet of unlined levee six feet high and 1800 feet of levee twelve feet high with three to one slopes on both sides and top width of ten feet.

Two gates for diversion for spreading would be installed in the last 3000 feet of dike.

The work on City Creek is estimated to cost about $49,500. Details are to be found on page 67.

*Mill Creek.**—The present diversion dam to spreading works would be strengthened, and at the lower side of the spreading works a levee 14,500 feet long is proposed to protect cultivated lands. The levee would have an average height of six feet, top width of ten feet with twotwo to one and three to one slopes.

The cost is estimated at $42,800 and details are given on page 69.

*San Timoteo Creek.**—This phase of the work would require 23,200 feet of levee on each side after the creek enters the flat lands. The levees would be six feet high with a top width of ten feet and two to one and three to one slopes. Three drops in the vicinity of Redlands and above also would be required to stop cutting by the stream.

Details of this plan, costing $140,800, are to be found on page 69.

* See Plate X.

This would require 3400 feet of unlined levee six feet high and 1800 feet of levee twelve feet high with three to one slopes on both sides and top width of ten feet.

Two gates for diversion for spreading would be installed in the last 3000 feet of dike.

The work on City Creek is estimated to cost about $49,500. Details are to be found on page 67.

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Details of this plan, costing $140,800, are to be found on page 69.

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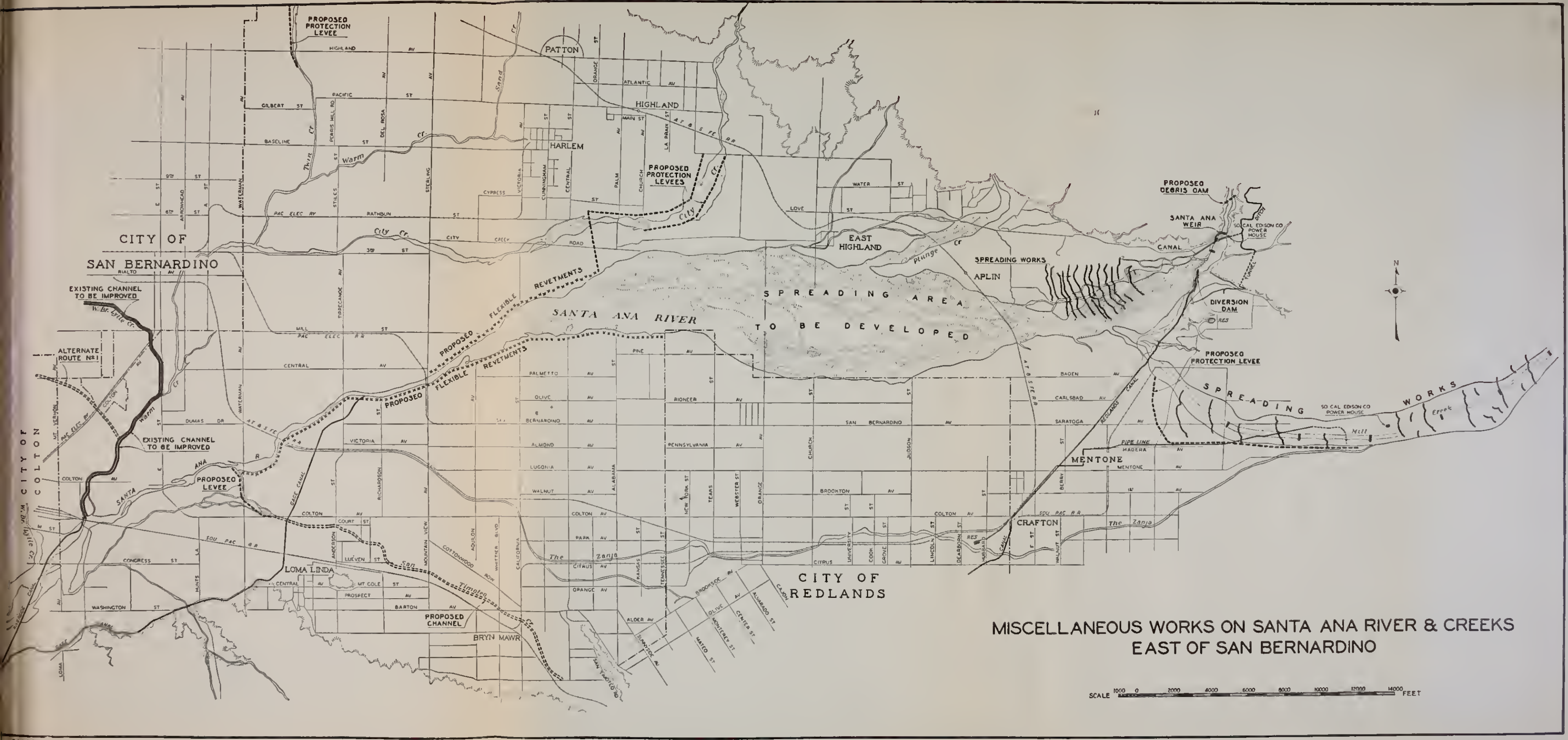
* See Plate X.



MISCELLANEOUS WORKS ON SANTA ANA RIVER & CREEKS
EAST OF SAN BERNARDINO

CHAPTER VI

UPPER SANTA ANA RIVER

On Santa Ana River the first percolating area in Upper Basin begins at the mouth of the canyon and extends to a point seven miles below the mountains where Bunker Hill Dike begins to make its presence felt and forces water to the surface for a distance of six miles. Next comes another percolating area seven miles long in Jurupa Basin, in the vicinity of Colton, and the third area on the Coastal Plain, just below the mouth of Lower Santa Ana Canyon, is about 17 miles long.

The waste land in the debris cone, which comprises the uppermost percolating area, totals about 5000 acres. Water has been diverted to the north side of the cone for spreading at the mouth of the canyon by the Water Conservation Association of the three counties since 1912. By agreement no water has been thus diverted unless the river was flowing at Chapman Avenue Bridge in Orange County. It is not known at what flows spreading has ceased under this agreement, nor are data in existence which show how much percolation will occur in the stream above Bunker Hill Dike and in the percolating areas below the dike, independent of the spreading works.

The efficiency of the spreading works has suffered because the diversion works, up to this year, have not been of permanent character and have been washed out in floods of consequence. After subsidence of the flood it always has been several days, and often much longer, before adequate diversions could again be made. Thus, in many years, a large proportion of the period in which spreading could go on, under the stipulation above noted, has been lost. In the summer of 1930 a permanent rubble masonry weir was constructed across the wash at the canyon mouth and a conduit of 1000 second-foot capacity constructed to the spreading areas. This work, shown in Plate X, is being done by the Water Conservation Association and is to be completed before the rainy season of 1930–31.

The spreading works, as now constructed. cover approximately 400 acres out of a total of 5000 acres in the debris cone. Percolation is induced by ponding the water behind rubble masonry walls and earth dikes constructed transverse to the slope of the cone. On the ridges between channels water spills over the walls and, after irrigating the ridges, flows back to the channels whence it is again diverted. Unit rates of percolation are not known, but the capacity of the works is estimated at 400 second-feet by the association.

Water has been diverted only after it is partially cleared in order that the porous soil will not be sealed by fine sediment. The time required for the water to clear after a storm is variously stated to be from one to three days, and occasionally it may be longer. The time required is believed to vary with the magnitude of the flood and also with the time of year. It also depends on whether the flood is the first flood of the year or a subsequent one.

In very dry years there are no floods of consequence. In other years, both moderately dry and moderately wet, there may be only one or two floods, and in wet years there may be several. In the first flood much debris and much loose and fine material is brought down, but succeeding rains compact the soil and, most of the loose material having been washed down in the first flood, the stream clarifies much sooner in succeeding floods. Sometimes with the well sustained flows of the wetter seasons following the first flood, water will be clear enough to divert at much higher discharges than is the case in the first flood.

A reservoir in the canyon above is desirable under these conditions to improve the efficiency of the spreading works. This would hold back the water on the days when it is too muddy to spread and, being clarified in the reservoir, it could be released later and diverted without causing trouble. The reservoir, irrespective of condition of the water, would also hold back the peaks when the flow is greater than capacity of diversion works and thus increase the amount which could be spread.

A reservoir of 70,100 acre-foot capacity exists at Bear Lake on Bear Creek, the principal tributary to Santa Ana River in the mountain watershed. This was built and is operated purely for long-time storage and not as an adjunct to spreading. The entire watershed has been surveyed, but only three reservoirs were found. These are:

> At Filirea Flats, on South Fork of Santa Ana River, 2½ miles above junction with Bear Creek; surveyed to a capacity of 4000 acre-feet with height of dam 178 feet above estimated location of bedrock. The dam site was not drilled as the rock on side walls is of good quality. Drainage area above is 87 square miles.
>
> At junction of Bear Creek and South Fork, called Forks site; dam site immediately below the junction surveyed to a capacity of 20,000 acre-feet with height of dam 315 feet above estimated location of bedrock. The dam site was drilled with a hole on both sides converging toward the center and the quality of rock appeared suitable. Drainage area above, exclusive of that above Bear Valley reservoir, is 138 square miles.
>
> Near Mentone, just above mouth of Santa Ana Canyon; surveyed to a capacity of 25,000 acre-feet with height of dam 310 feet above estimated location of bedrock. The dam site was not drilled. Drainage area above, exclusive of that above Bear Valley reservoir, is 161 square miles. Preliminary estimate of cost was $19,000,000 or $760 per acre-foot, but since this estimate was made standards of gravity dam construction have been revised by the state and dams made heavier and a new estimate of cost now would be higher. The Mentone site has not been further considered in this report.

Stream Flows.

Discharge Records.—Daily records of the river discharge at Mentone since July 1, 1896, are available, except for periods in 1910, 1916 and 1927 when the gage was washed out and records of daily discharges for the major floods of those years are incomplete or entirely lacking. Daily records of canal discharge past the river gaging station at Mentone, beginning with the year 1908, also are available. Prior to that time only monthly records are published.

Records of change of contents of and spill from Bear Valley reservoir since 1890, likewise are available.

Estimate of discharge at Forks reservoir.—Only discharges larger than capacity of spreading diversions are important, or discharge during the first three days of flood, whether larger than diversion capacity or not.

Discharge of river only at Mentone has been used, the canal discharge being neglected and the discharge at Forks is assumed to be the same as that at Mentone.

Corrections for reduction in flow, due to changes in capacity of Bear Valley reservoir, were made by subtracting from the Mentone records for each day the additional storage which would have been impounded in Bear Valley reservoir had it been built, at the time of record, to present capacity.

Estimate of discharge at Filirea reservoir.—Only discharges larger than capacity of spreading diversions, or discharge during first three days of flood, whether larger than diversion capacity or not, likewise are the only ones of importance here.

The flow of the river and canals at Mentone were added to arrive at this figure. The discharge at Mentone also was reconstructed to what it would have been if Bear Valley reservoir did not exist, by adding to each day's flow the total storage for the same day.

On this basis the discharge at Filirea was estimated to be 46 per cent of total reconstructed flow at Mentone for the period prior to October, 1914, and 44 per cent for the period subsequent to that date. The difference is due to a change in location of the measuring station in October, 1914. These percentages were based upon a direct ratio between the drainage areas above Mentone and the drainage area above Filirea.

The period since 1908 only was used in this phase of the investigation. Daily records for canals were not published prior to that year and it was found that this shorter period gave approximately same average at Forks reservoir as the longer period beginning in 1896.

Estimate of diurnal variations in flood discharge.—An automatic stage recorder was installed at Mentone gaging station in 1917. From this record the changes in discharge during each day's flood were observed to determine the relation between the peak of the flood and the average day's discharge. This was desired in order to deduce an approximate law by which the number of hours when the flow was above 1000 second-feet could be estimated from records before installation of recorder, when only average day's flow is available.

Analyses.

These records were analyzed to determine how much water would escape past diversion works of 1000 second-foot capacity for spreading on Santa Ana cone. Two assumptions were made—

(a) Diversions not made during first day of flood;
(b) Diversions not made during first three days of flood.

The results are shown in the following table and in this also is shown the reservoir capacity necessary to conserve the discharge past the diversion works.

POSSIBLE WATER SALVAGE BY RESERVOIRS ON HEADWATERS OF THE SANTA ANA RIVER

Seasonal year	Escape past 1,000 cubic feet per second spreading works		Storage capacity required to conserve amounts in columns 1 and 2		Remarks
	No diversion first day of flood, acre-feet	No diversion first three days of flood, acre-feet	No diversion first day of flood, acre-feet	No diversion first three days of flood, acre-feet	
1896-97	3,240	5,970	1,240	2,400	
1897-98	0	0	0	0	
1898-99	0	0	0	0	
1899-00	0	0	0	0	
1900-01	5,210	8,805	3,130	4,325	
1901-02	0	0	0	0	
1902-03	13,220	16,840	13,220	16,840	
1903-04	0	0	0	0	
1904-05	0	0	0	0	
1905-06	11,540	19,875	4,990	9,455	
1906-07	10,970	19,470	2,410	5,880	
1907-08	0	0	0	0	
1908-09	4,830	7,300	2,670	3,275	
1909-10	----------	----------	----------	----------	Record not complete. Large escape.
1910-11	5,145	9,220	2,540	6,200	
1911-12	0	0	0	0	
1912-13	0	0	0	0	
1913-14	7,340	12,460	5,090	8,270	
1914-15	0	0	0	0	
1915-16	----------	----------	----------	----------	Record not complete. Large escape.
1916-17	0	0	0	0	
1917-18	18,190	23,230	15,230	23,230	
1918-19	0	0	0	0	
1919-20	3,950	7,105	1,870	3,105	
1920-21	1,055	1,615	1,055	1,615	
1921-22	10,050	22,225	2,730	6,650	
1922-23	1,180	1,740	1,180	1,740	
1923-24	0	0	0	0	
1924-25	0	0	0	0	
1925-26	1,675	4,405	1,675	4,405	
1926-27	----------	----------	----------	----------	No record during flood.
1927-28	0	0	0	0	
1928-29	0	0	0	0	
1929-30	0	0	0	0	

It is desired to determine the amounts of water reservoirs of various capacities at Filirea and Forks would conserve. The amounts which would have passed in the years of record can not be determined for the three high years because the record was lost during the floods. However, rainfall records indicate that any of the reservoir capacities studied would have been filled during the large floods of those years and with that assumption the accomplishment of the reservoirs can be determined. To do this the record of each day during each flood for the past thirty-four years was used and reservoir content for each day was calculated, the draft being taken at 1000 cubic feet per second, the capacity of diversion to spreading works, in accordance with assumptions given below.

Accomplishment of Forks Reservoir.*

Assumption 1.

Reservoir capacity 10,000 acre-feet.
Spreading starts on second day of flood.
Spreading diversion 1000 second-feet.

The following estimated quantities can be spread and thus conserved, as against spreading starting on second day without reservoir:

Period	*Average annual amount spread*
1906–1916	6,030 acre-feet
1917–1930	2,920 acre-feet
1897–1930	3,700 acre-feet

Assumption 2.

Reservoir capacity 10,000 acre-feet.
Spreading starts on fourth day of flood.
Spreading diversion 1000 second-feet.

The following estimated quantities can be spread and thus conserved, as against spreading starting on fourth day without reservoir:

Period	*Average annual amount spread*
1906–1916	9,280 acre-feet
1917–1930	4,080 acre-feet
1897-1930	5,410 acre-feet

Assumption 3.

Reservoir capacity 6000 acre-feet.
Spreading starts on second day of flood.
Spreading diversion 1000 second-feet.

The following estimated quantities can be spread and thus conserved, as against spreading starting on second day without reservoir:

Period	*Average annual amount spread*
1906–1916	5,300 acre-feet
1917–1930	2,350 acre-feet
1897–1930	3,110 acre-feet

Assumption 4.

Reservoir capacity 6000 acre-feet.
Spreading starts on fourth day of flood.
Spreading diversion 1000 second-feet.

The following estimated quantities can be spread and thus conserved, as against spreading starting on fourth day without reservoir:

Period	*Average annual amount spread*
1906–1916	7,890 acre-feet
1917–1930	3,430 acre-feet
1897–1930	4,570 acre-feet

* Inasmuch as the discharge at Forks reservoir is assumed to be the same as at Mentone in making these calculations, the calculated performance of Forks reservoir is greater than actual.

Accomplishment of Filirea Reservoir.

Assumption 5.

Spreading starts on second day of flood.

Period	*Average annual amount spread*
1917–1930	1,640 acre-feet
1909–1930	2,120 acre-feet

Assumption 6.

Spreading starts on fourth day of flood.

Period	*Average annual amount spread*
1917–1930	2,060 acre-feet
1909–1930	2,760 acre-feet

Comment.

It is believed that neither the assumption that, for each flood, spreading can start the second day or that it can not start until the fourth day is correct. The following tabulation show the mean of each pair of above assumptions and it is believed that this quantity will more nearly be the truth than either of the basic assumptions.

Average Annual Quantities Conserved by Reservoirs in Santa Ana Canyon in Acre-feet

Period	*Filirea Flats reservoir 4,000 acre-feet*	*Forks reservoir 6,000 acre-feet*	*Forks reservoir 10,000 acre-feet*
1906–1916	----	6,590	7,650
1917–1930	1,850	2,890	3,500
1897–1930	2,440*	3,840	4,560

Cost of Reservoirs.

Estimated costs of the several reservoirs, based on gravity concrete overflow dams, details of which are given on pages 70, 71 and 73 and also on Plate XV, are set forth in the following table:

ESTIMATED COSTS OF RESERVOIRS

	Acre-feet capacity	Height above stream bed	Estimated depth of stripping on bottom in feet	Average annual yield in acre-feet	Estimated cost: Total	Estimated cost: Per acre-foot of yield	Estimated cost: Per acre-foot of additional yield
Filirea Flats	4,000	178	15	2,440	$1,693,000	$670	----------
Forks	6,000	196	90	3,840	2,994,000	776	$954
Forks	10,000	243	90	4,560	4,372,000	956	1,915

Forks site is below the rapidly disintegrating section of the stream bed and will fill with debris more quickly than the Filirea site.

* For period 1909–1930, which gives results practically the same as long-time average in the case of Forks reservoir and is therefore assumed to do so for Filirea reservoir.

The community served by Santa Ana River is established and the type of agriculture practiced brings large average returns. It is believed that an auxiliary supply to this territory would justify much greater expenditure per acre-foot of water than is generally considered feasible. However, to justify such an expenditure there must be an actual shortage. As shown in Bulletin 19, the water plane under the cone at the mouth of Santa Ana Canyon rose an average of 23 feet between 1904 and 1928. This does not indicate overdraft. With present knowledge it is believed improbable that there will be overdraft, even ultimately, for certainly the spreading works now under construction will add to the supply. If the reservoir site in Lower Santa Ana Canyon did not exist and if there were a shortage in sight, the cost of the upper one might be justified. If there is no shortage in the cone, salvage by Forks or Filirea reservoirs would be only for the Lower Basin and this can be accomplished more cheaply at the site in lower Santa Ana Canyon. Future requirements and developments may, however, make the Filirea or Forks site desirable.

Development in Canyons.

An alternative to a reservoir in the upper canyon might be development of the underground waters of the gravel areas in the stream beds of the mountains. The limitations of such development are not known now, but the matter appears meritorious. Likewise, rockfill dams constructed at narrow points in the canyon to raise the water not more than 50 feet and located where a spillway could be constructed in a solid rock ridge on the side of the stream, would add to the water supply. These also would serve as barriers behind which debris would lodge and make spreading diversions easier because of removal of part of the debris.

On both the Santa Ana River and Lytle Creek such dams would be desirable, but they are more advantageous on Lytle Creek than on the headwaters of the river because of the unstable condition of the stream across Lytle Creek cone. The problem of debris deposition in the valley is a peculiarly serious one on that cone and such dams would aid in its solution. On the Santa Ana River this problem is not acute.

It is believed more can be accomplished in the way of conservation per dollar spent, by dams such as outlined and by utilization of existing gravel beds than by reservoir construction. This has also the advantage in that it lends itself to progressive development. Regardless of this, however, such dams would aid in spreading on Santa Ana cone. They would do this also on the Lytle Creek cone, but in this case they would also aid in flood control by removing debris.

Santa Ana Spreading Works.*

The present works cover about 400 acres, but it is believed that there should be about 1200 acres ultimately covered to take care of 1000 second-feet. The estimated cost of the additional works is $350,400, and this is detailed on page 67.

* See Plate X.

Santa Ana River Revetments.*

On the south bank, opposite the City Creek influx, there exists a weak spot and it is desirable to confine the river to protect property. On the north bank, from the new point of entrance of City Creek to the Pacific Electric crossing there also is a weak low bank and if the river breaks over at this point the lower end of the city of San Bernardino will be flooded. The material here is very sandy. In view of all conditions it is believed flexible bank protection would be the best to use.

The south bank requires protection for a distance of 25,000 feet and the north bank for 11,700 feet. One line of bank protection structure on the south side and two lines on the north side are proposed at a total cost estimated at $219,300, detailed on page 68.

* See Plate X.

CHAPTER VII

LOWER SANTA ANA RIVER *

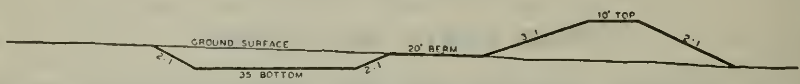
Since no further work was done at or below Lower Santa Ana Canyon during the present biennium, the items herein included are taken from the report of the Chief Engineer of Orange County Flood Control District dated April, 1929, and from Bulletin 19. The items considered are a reservoir in Lower Santa Ana Canyon, channel improvements below and two reservoirs of 26,000 acre-feet total capacity on Santiago Creek.

It also has been stated earlier in this report that the plan previously proposed by the district is being studied by a board of engineers retained by Orange County Flood Control District and a report, which may recommend revisions in the plan, is expected in due time.

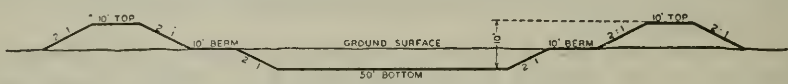
If the Orange County Flood Control District plans are consummated, the features set forth on page 11 for Lower Santa Ana River, together with many other features on streams not tributary to the river, will be undertaken by that body.

* See Plate II.

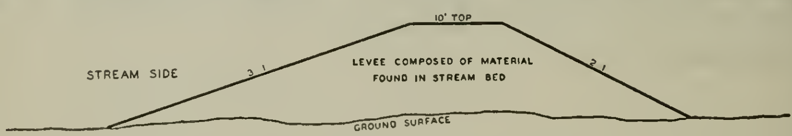
PLATE XI



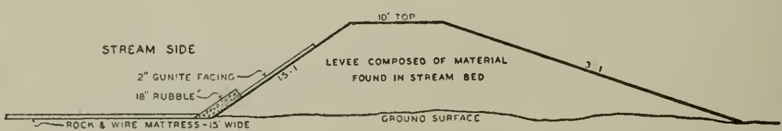
TYPICAL SECTION OF SPREADING WORKS CHANNEL



TYPICAL SECTION OF FLOOD CHANNEL



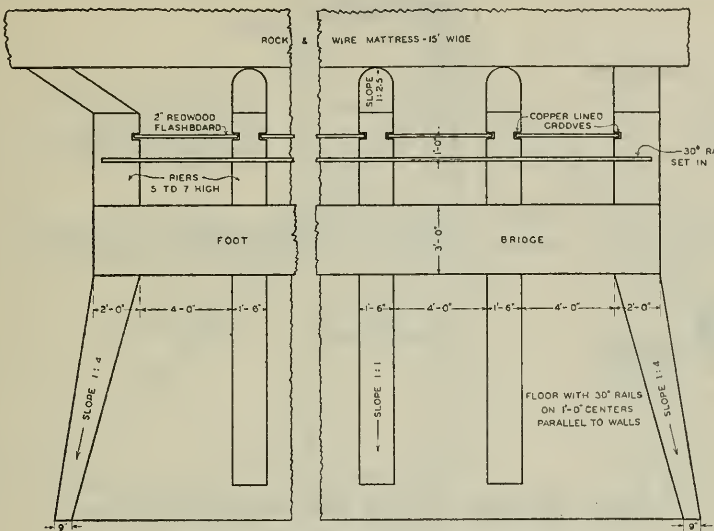
TYPICAL SECTION OF UNLINED DIKE



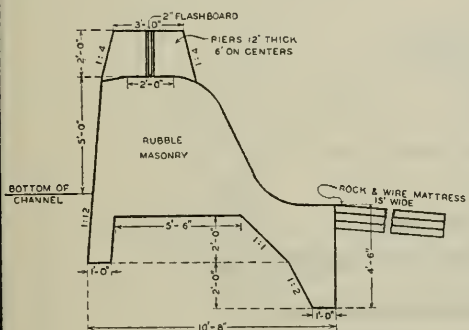
TYPICAL SECTION OF LINED DIKE

STRUCTURAL DETAILS

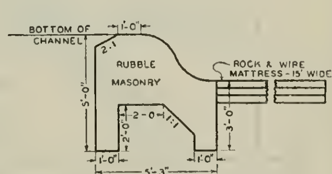
PLATE XII



PLAN OF TYPICAL GATE STRUCTURE
CONCRETE



TYPICAL SPILLWAY SECTION
OF DIVERSION WALL

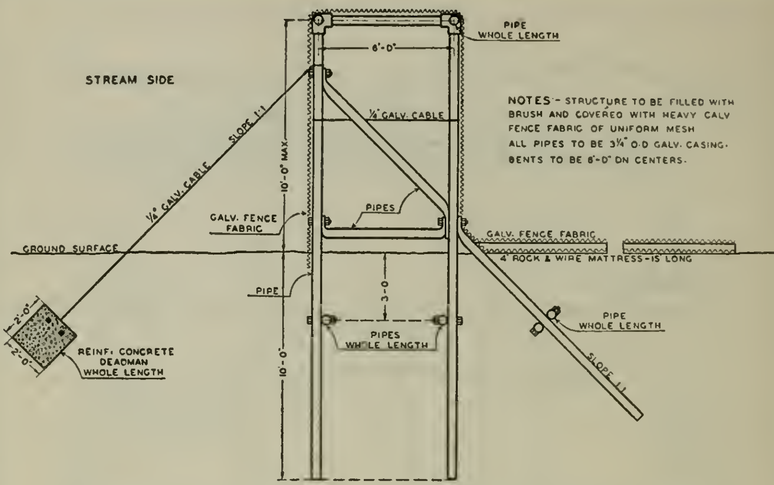


TYPICAL SECTION
OF CROSS WALL

STRUCTURAL DETAILS

SCALE
INCHES 12 0 2 4 6 8 10 FEET

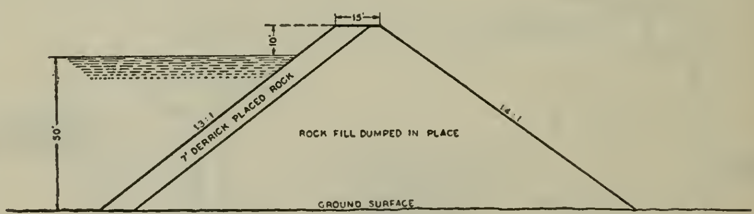
PLATE XIII



TYPICAL SECTION OF PIPE AND WIRE DEBRIS DAM

SCALE

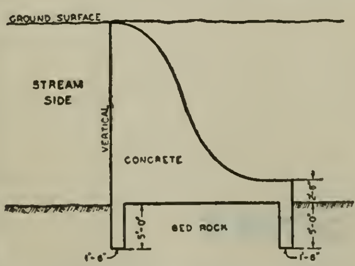
INCHES 12 0 2 4 6 8 10 12 14 FEET



TYPICAL SECTION OF ROCK FILL DAM

SCALE

FEET 10 0 10 20 30 40 50 60 70 80 90 100 FEET



TYPICAL SECTION OF CONCRETE GRAVITY DEBRIS DAM

SCALE

INCHES 12 0 2 4 6 8 10 12 14 16 18 20 FEET

STRUCTURAL DETAILS

PLATE XIV

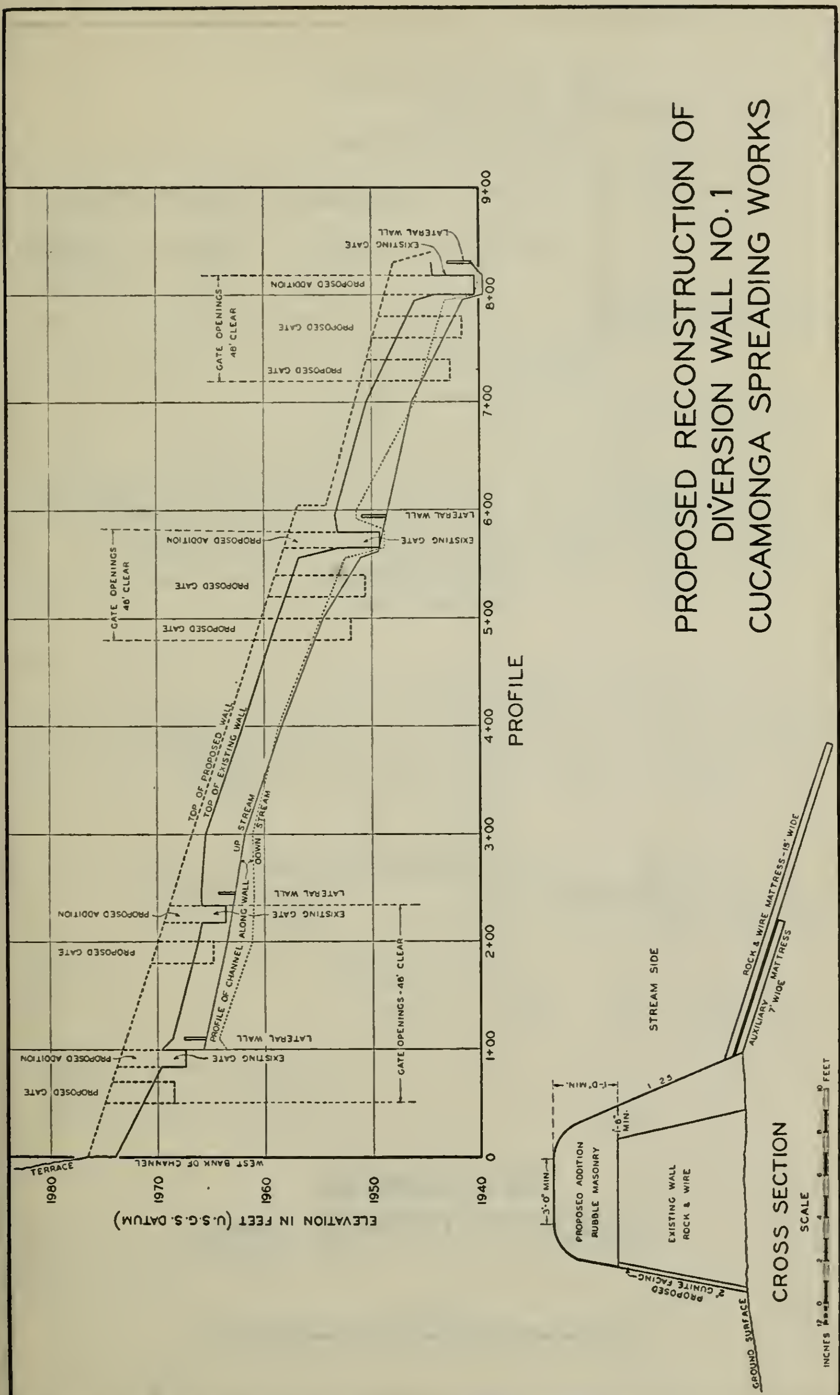
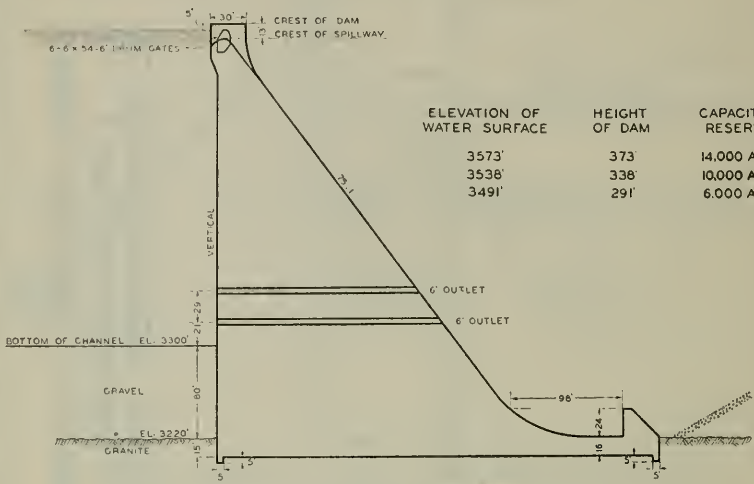
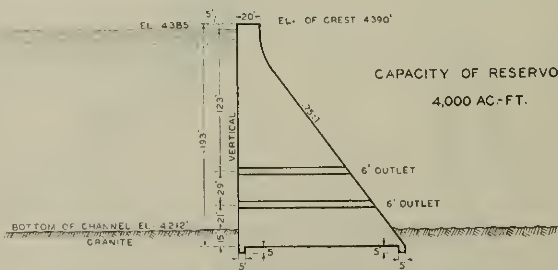

PROPOSED RECONSTRUCTION OF
DIVERSION WALL NO. 1
CUCAMONGA SPREADING WORKS
PROFILE
ELEVATION IN FEET (U.S.G.S. DATUM)
1980
1970
1960
1950
1940
0
1+00
2+00
3+00
4+00
5+00
6+00
7+00
8+00
9+00
TERRACE
WEST BANK OF CHANNEL
PROPOSED GATE
PROPOSED ADDITION
EXISTING GATE
LATERAL WALL
GATE OPENINGS - 48' CLEAR
TOP OF PROPOSED WALL
TOP OF EXISTING WALL
PROFILE OF CHANNEL ALONG WALL
UP STREAM
DOWN STREAM
CROSS SECTION
SCALE
INCHES
FEET
STREAM SIDE
PROPOSED ADDITION
RUBBLE MASONRY
EXISTING WALL
ROCK & WIRE
PROPOSED 2" GUNITE FACING
GROUND SURFACE
ROCK & WIRE MATTRESS - 15' WIDE
AUXILIARY MATTRESS 7' WIDE
3'-0" MIN.
1'-0" MIN.
1'-6" MIN.
1 : 2.5

PLATE XV



DAM AT FORKS

USED FOR ESTIMATE



DAM AT FILIREA

USED FOR ESTIMATE

SECTIONS OF CONCRETE GRAVITY DAMS

SCALE

FEET 50 0 50 100 150 200 250 300 FEET

CHAPTER VIII

COST ESTIMATES

PROPOSED SAN ANTONIO CHANNEL IMPROVEMENT*

Protection Levee Above Holt Avenue on East Bank.

Length, 9000 feet. Top width, ten feet. Side slopes, two to one on land side and three to one on stream side. No excavation in channel. Average height, eight feet above ground surface and twelve feet above bottom of channel.

Channel Improvement from Holt Avenue Southerly.

Length, 42,000 feet. Ditch, minimum bottom width, 80 feet. Side slopes two to one. Berms, ten feet wide at ground surface. Levee, top twelve feet above bottom of channel, as shown in cross-section on Plate XI. Capacity, 10,000 second-feet. Where natural channel is 180 feet or more in width, top of levees would be ten feet above grade, without berm.

Road Crossings.

For major roads, standard plans of Division of Highways for concrete culverts would be used. Minor roads would be crossed by placing a dip in road and paving road with twelve-inch paving. Toe wall five feet deep and one foot thick would be placed on each side of paving.

COST OF PROPOSED SAN ANTONIO CHANNEL IMPROVEMENT

Item	Unit	Quantity	Unit cost	Item cost	Total cost
Earth work—					
Sand and gravel	Cubic yard	210,800	$0 20	$42,160	
Sand	Cubic yard	504,500	0 12	60,540	$102,700
Structures—					
New concrete road culvert of three openings 21 feet wide		1	10,080 00	$10,080	
Additions to present road culverts: One concrete structure with opening 20 feet wide		10	2,016 00	20,160	
Paved road crossings—					
Four roads	Cubic yard	780	15 00	11,700	41,940
Base cost					$144,640
Administration, engineering and contingencies			25 per cent		36,160
Interest during construction at 6 per cent					2,700
Right of way					134,000
Grand total					$317,500

* See Plate III.

PROPOSED CUCAMONGA CREEK SPREADING WORKS*

Deflection Levee Above Diversion Wall No. 1.†

Length, 650 feet. Average height, seven feet.

Diversion Wall No. 1.‡

Present wall strengthened and raised. Concrete gate structures in diversion wall as shown in Plate XII. Estimated in sets of four openings. Rubble masonry cross walls below gate structures and at right angles to diversion wall upstream side to prevent scour.

Diversion Wall No. 2.§

Same type structure as Wall No. 1, with only one gate structure.

Spreading Channels.

Formed by low embankments on downhill side of wide shallow excavation. Capacity, 1000 second-feet each. Length, 46,425 feet. Depth, eight feet. Section shown in Plate XI.

COST OF PROPOSED CUCAMONGA CREEK SPREADING WORKS

Item	Unit	Quantity	Unit cost	Item cost	Total cost
Earth work—					
Coarse gravel	Cubic yard	536,400	$0 30	$160,920	
					$160,920
Structures—					
Diversion walls:					
Rubble masonry	Cubic yard	1,100	8 00	8,800	
Gunite facing	Square feet	12,310	0 16	1,970	
Rock and wire mattress	Square feet	29,300	0 20	5,860	
Gate units		10	1,000 00	10,000	
					26,630
Base cost					$187,550
Administration, engineering and contingencies			25 per cent		46,900
Interest during construction at 6 per cent					6,950
Grand total					$241,400

* See Plate IV.
† See Plate XI.
‡ See Plate XIV.
§ See Plate XII.

PROPOSED DEER AND DAY CREEKS SPREADING WORKS*

Main Diversion Channels.

Formed by low embankments on downhill side of wide shallow excavation. Capacity, 3000 second-feet. Length, 4000 feet. Depth, twelve feet. For section see Plate XI.

Spreading Channels.

Formed by low embankments on downhill side of wide shallow excavation. Capacity, 1000 second-feet each. Length, 60,000 feet. Depth, eight feet. For section see Plate XI.

Structures.

Rubble masonry spillways in present creek channels. Concrete gate structures in embankment of main diversion channels to divert to spreading channels. Rubble masonry cross walls in main diversion channel below spillway and below gate structures to prevent scour. Sections of spillways, gate structures and cross walls shown in Plate XII.

COST OF PROPOSED DEER AND DAY CREEKS SPREADING WORKS

Item	Unit	Quantity	Unit cost	Item cost	Total cost
Earth work—					
Coarse gravel	Cubic yards	566,700	$0 30	$170,010	$170,010
Structures—					
Spillways in diversion levees		2	2,100 00	$4,200	
Spillway from spreading grounds to flood channel				15,880	
Gate units with four 4 foot openings		5	1,000 00	5,000	
Diversion walls:					
Rubble masonry	Cubic yards	375	8 00	3,000	
Rock and wire mattress	Square feet	2,900	0 20	580	
					28,660
Base cost					$198,670
Administration, engineering and contingencies			25 per cent		49,670
Interest during construction at 6 per cent					7,360
Right of way					84,000
Grand total					$339,700

* See Plate VI.

PROPOSED CUCAMONGA CREEK FLOOD CHANNEL*

Channel Improvement from Pacific Electric Bridge Southeasterly.

Channel, length, 55,000 feet. Bottom width above Deer and Day Creek junction, 50 feet. Bottom width below junction, 60 feet. Berm, 20 feet wide at ground surface. Levee, height, ten feet above bottom of channel. For section see Plate XI. Capacity, 5000 second-feet above and 6000 second-feet below junction with Deer and Day channel.

Road Crossings.

For major roads, standard plans of Division of Highways for concrete culverts would be used. Minor roads would be crossed by placing a dip in road and paving road with twelve-inch paving. Toe wall five feet deep and one foot thick would be placed on each side of paving.

COST OF PROPOSED CUCAMONGA CREEK FLOOD CHANNEL

Item	Unit	Quantity	Unit cost	Item cost	Total cost
Earth work—					
Sand and gravel	Cubic yards	52,500	$0 20	$10,500	
Sand		784,400	0 12	94,130	
					$104,630
Structures—					
New concrete road culverts of two openings 21 feet wide		3	6,720 00	$20,160	
New railroad bridges 45 feet clear span through girder type		3	4,590 00	13,770	
Paved road crossings		10	395 00	39,500	
					73,430
Base cost					$178,060
Administration, engineering and contingencies			25 per cent		44,515
Interest during construction at 6 per cent					6,725
Right of way					261,000
Grand total					$490,300

* See Plate V.

PROPOSED DEER AND DAY CREEK FLOOD CHANNEL*

Channel Improvement from Highland Avenue to Cucamonga Channel.

Capacity, 4000 second-feet. Unlined ditch above Haven avenue and below Colton boulevard. Earth channel, length, 22,100 feet; section shown Plate XI. Haven avenue, paved 40 feet wide, curbs 4 feet high. Spillways out of spreading grounds and above Haven avenue as shown in Plate XII.

Road Crossings.

For major roads, standard plans of Division of Highways for concrete culverts would be used. Minor roads would be crossed by placing a dip in road and paving road with twelve-inch paving. Toe wall five feet deep and one foot thick would be placed on each side of paving.

COST OF PROPOSED DEER AND DAY CREEK FLOOD CHANNEL

Item	Unit	Quantity	Unit cost	Item cost	Total cost
Earth work—					
Sand and gravel	Cubic yards	113,850	$0 20	$22,770	
Sandy loam	Cubic yards	10,250	0 12	1,230	
					$24,000
Structures—					
Spillway at Haven avenue rubble masonry	Cubic yards	1,030	8 00	$8,240	
Paving Haven avenue, miscellaneous inlet and outlet structures and curbs	Lineal feet	11,000	6 30	69,300	
New concrete road culverts of two openings 21 feet wide		2	6,720 00	13,440	
Railroad bridges 40 feet clear span through girder type		2	4,750 00	9,500	
45 feet clear span through girder type		1	5,250 00	5,250	
80 feet clear span wood pile trestle	Lineal feet	80	15 00	1,200	
Protection works at junction with Cucamonga channel	Cubic yards	100	15 30	1,530	
Reinforced concrete gunite facing	Square feet	24,500	0 16	3,920	
					112,380
Paved road crossings—					
Two roads	Cubic yards	290	15 00	$4,350	
Rock and wire mattress	Square feet	1,050	0 20	210	
					4,560
Base cost					$140,940
Administration, engineering and contingencies			25 per cent		35,240
Interest during construction at 6 per cent					5,320
Right of way					47,000
Grand total					$228,500

* See Plate V.

PROPOSED ONTARIO FLOOD CHANNEL*

Channel located along south side of Eighth street from East line city of Ontario to Cucamonga Channel. Length, 7400 feet. Bottom width, 30 feet. Side slopes, two to one. Capacity, 7500 second-feet. Depth, six feet.

COST OF PROPOSED ONTARIO FLOOD CHANNEL

Item	Unit	Quantity	Unit cost	Item cost	Total cost
Excavation—					
Gravel soil	Cubic yards	17,500	$0 50	$8,750	
					$8,750
Base cost					
Administration, engineering and contingencies			25 per cent		2,150
Interest during construction					0
Right of way					39,000
Grand total					$49,900

* See Plate V.

PROPOSED LYTLE CREEK SPREADING WORKS*

Deflection Levee Above Present Dam.

Length, 4000 feet. Complete section shown in Plate XI.

Diversion Works.

Present dam would be used for spillway 450 feet long. Roller gates 50 feet long installed on east end of dam to scour sand from front of diversion headworks. Gate structures proposed are shown by section in Plate XII. Diversion channel shown by section in Plate XI, which also shows spreading channels. Diversion dams and cross-walls are similarly shown in Plate XII.

COST OF PROPOSED LYTLE CREEK SPREADING WORKS

Item	Unit	Quantity	Unit cost	Item cost	Total cost
Earth work—					
Coarse gravel	Cubic yards	175,700	$0 30	$52,700	
					$52,700
Structures—					
Diversion dams:					
Cross walls of rubble masonry	Cubic yards	240	8 00	$1,920	
Check dams of rubble masonry	Cubic yards	3,660	8 00	29,280	
Deflection walls of rock and wire	Cubic yards	9,870	8 00	78,960	
Gates:					
Manually operated gates				7,000	
Roller gates				12,440	
					129,600
Rock and wire mattress—					
Four inches thick by fifteen feet wide	Square feet	91,500	0 20	$18,300	
					18,300
Base cost					$200,600
Administration, engineering and contingencies			25 per cent		50,150
Interest during construction at 6 per cent					7,550
Right of way					100,000
Grand total					$358,300

* See Plate VII.

PROPOSED LYTLE CREEK FLOOD CHANNEL*

Channel Improvements from Santa Fe Main Line Southerly.

The channel would follow the old course, called the East Branch. Length, 25,700 feet. Minimum bottom width, 140 feet. Side slopes, two to one. Depth, twelve feet. Top width of levees in low spots, ten feet. Capacity, 20,000 second-feet above and 25,000 second-feet below junction with Warm Creek.

Colton channel improved to carry 5000 second-feet. Headworks just below Santa Fe Railroad.

COST OF PROPOSED LYTLE CREEK FLOOD CHANNEL

Item	Unit	Quantity	Unit cost	Item cost	Total cost
Earth work—					
Sand and gravel	Cubic yards	780,000	$0 20	$156,000	$156,000
Structures—					
Diversion works				$ 4,000	
Addition to present road culvert, two openings 21 feet wide				6,700	
Channel protection				28,600	39,300
West branch improvements—					
Channel through Colton				$20,000	20,000
Base cost					$215,300
Administration, engineering and contingencies			25 per cent		53,825
Interest during construction at 6 per cent					8,075
Grand total					$277,200

* See Plate VIII.

ALTERNATE PLAN No. 1 LYTLE CREEK FLOOD CHANNEL*

(Channel Through Colton)

Channel Improvements from Santa Fe Main Line Southerly.

Channel, length, 20,700 feet. Colton Channel improved for first 7600 feet, then easterly in new channel for 7600 feet to Warm Creek. Warm Creek channel improved for 5500 feet. Minimum bottom width 80 feet. (Section shown in Plate XI.) Capacity, 10,000 second-feet to Warm Creek, then 30,000 second-feet to Santa Ana River. East Branch Channel unimproved to carry 15,000 second-feet.

COST OF ALTERNATE PLAN No. 1 LYTLE CREEK FLOOD CHANNEL

(Channel through Colton)

Item	Unit	Quantity	Unit cost	Item cost	Total cost
Earth work—					
Sand and gravel	Cubic yards	102,800	$0 20	$20,560	
Sandy loam	Cubic yards	486,800	0 15	73,020	
					$93,580
Structures—					
Diversion works				$13,600	
New concrete highway bridges, two 40 foot spans, 30 foot roadway		2	5,300 00	10,600	
One 80 foot span, 20 foot roadway		1	6,050 00	6,050	
New concrete road culvert of four openings 21 feet wide		1		20,160	
Addition to present road culvert, two openings 21 feet wide		1		6,720	
New railroad and highway bridge 100 feet clear span, total width 84 feet				50,700	
Channel protection				104,500	
					212,330
Paved road crossings—					
Two roads	Cubic yards	640	15 00	$9,600	
					9,600
Base cost					$315,510
Administration, engineering and contingencies			25 per cent		78,880
Interest during construction at 6 per cent					11,910
Right of way					177,000
Grand total					$583,300

* See Plate VIII.

ALTERNATE PLAN No. 2 LYTLE CREEK FLOOD CHANNEL*

(Artificial Channel West of Colton)

Channel Improvements from Santa Fe Main Line Southerly.

Channel, length, 23,700 feet. Capacity, 19,000 second-feet. Bottom width, 90 feet. Side slopes, two to one. Depth, twelve feet. Bank width ten feet. Lined throughout with gunite two inches thick. Drops totaling 120 feet are necessary. Headworks contain two steel gates 50 feet long and eight feet high. Spillway weir to old channel of 6000 second-feet capacity.

COST OF ALTERNATE PLAN No. 2 LYTLE CREEK FLOOD CHANNEL

(Artificial channel west of Colton)

Item	Unit	Quantity	Unit cost	Item cost	Total cost
Earth work—					
Soil	Cubic yards	807,700	$0 15	$121,155	
					$121,155
Structures—					
Diversion works:					
Concrete				$6,790	
Steel flood gates		2	13,070	26,140	
Concrete drops				68,800	
Railroad bridges, two 100 foot spans, girder type				35,500	
New road culverts each with five 21 foot openings, 22 foot roadway		3	8,400 00	25,200	
44 foot roadway		1	16,800 00	16,800	
Additions to present road culverts		1	6,720 00	6,720	
					185,950
Paved road crossings—					
Eight roads	Cubic yards	3,680	15 00	$55,200	
					55,200
Channel lining—					
2 inch gunite	Square feet	2,816,600	0 16	$450,655	
					450,655
Base cost					$812,960
Administration, engineering and contingencies			25 per cent		203,240
Interest during construction at 6 per cent					45,600
Right of way					306,000
Grand total					$1,367,800

* See Plate VIII.

PROPOSED LYTLE CREEK DEBRIS DAM*

This dam would be located 1000 feet above the Southern California Edison Company Power house. The features of the dam would be as follows:

Elevation stream bed, approximately	2,250 feet
Elevation crest, approximately	2,310 feet
Elevation flow line, approximately	2,300 feet
Depth of storage	50 feet
Total height	60 feet
Width of top	15 feet
Width of bottom	162 feet
Length of crest	830 feet
Type of dam	rock fill
Upstream slope	1.3 :1
Downstream slope	1.4 :1
Rock—cubic yards	133,058
Type of spillway	through cut around west end of dam
Length of spillway	300 feet
Capacity of spillway	19,000 second-feet
Depth of water in spillway	6 feet

COST OF PROPOSED LYTLE CREEK DEBRIS DAM

Item	Unit	Quantity	Unit cost	Item cost	Total cost
Dam—					
Dumped rock	Cubic yards	114,630	$1 75	$200,600	
Derrick placed rock on upstream face	Cubic yards	18,430	3 50	64,500	
					$265,100
Road—					
Reconstruction of road	Miles	1.5	25,000 00	37,500	
					37,500
Base cost					$302,600
Administration, engineering and contingencies			25 per cent		75,650
Interest during construction at 6 per cent					17,050
Grand total					$395,300

Note.—This dam is proposed at lowest favorable point in canyon to check debris in connection with spreading and flood control. When filled with debris it may be found possible to raise it. If not, another dam could be placed at a favorable point upstream.

* See Plate XIII.

PROPOSED DEVIL'S CANYON FLOOD CHANNEL*

Channel excavated to form bank on east and south sides. Side slopes excavation and embankment, two to one. Levee top width, ten feet. Berm at ground surface, ten feet.

Concrete culvert under Santa Fe. Opening, 20 feet wide, ten feet deep, length, 32 feet.

Concrete culvert under highway. Opening 20 feet wide, ten feet deep, length 44 feet.

COST OF PROPOSED DEVIL'S CANYON FLOOD CHANNEL

Item	Unit	Quantity	Unit cost	Item cost	Total cost
Earth work—					
Soil	Cubic yards	89,900	$0 15	$13,485	$13,485
Structures—					
Concrete:					
Road culvert				$3,360	
Railroad culvert				9,015	12,375
Base cost					$25,860
Administration, engineering and contingencies			25 per cent		6,460
Interest during construction					0
Right of way					7,880
Grand total					$40,200

* See Plate IX.

PROPOSED WATERMAN AND EAST TWIN CREEKS PROTECTION WORKS*

Waterman Creek.

Earth dam, 27 feet high, 2.5:1 downstream and 3:1 upstream slopes. Top width, 15 feet. Built of material excavated to form 20-foot bottom width, channel leading to east. This diverts Waterman Creek into East Twin Creek. Thirty-inch corrugated pipe through dam to take water to spreading grounds. Capacity of channel, 2800 second-feet.

East Twin Creek.

Levee, six feet high, five feet top width, side slopes, two to one. Length, 10,800 feet to channel into Warm Creek.

COST OF PROPOSED WATERMAN AND EAST TWIN CREEKS PROTECTION WORKS

Item	Unit	Quantity	Unit cost	Item cost	Total cost
Earth work—					
Sand and gravel	Cubic yards	37,800	$0 20	$7,560	
					$7,560
Structures—					
Diversion dam:					
Earth fill (unclassified)	Cubic yards	14,740	1 00	$14,740	
Sluice way				675	
					15,415
Base cost					$22,975
Administration, engineering and contingencies			25 per cent		5,725
Interest during construction					0
Right of way					14,200
Grand total					$42,900

* See Plate IX.

PROPOSED LITTLE SAND CREEK DEBRIS DAM*

Dam Construction.

Concrete gravity overflow dam on bedrock rising to bottom of present channel. Estimated height, 20 feet. Length, 145 feet.

Pipe and Wire Debris Barriers.

Twenty-foot pipe 3.25 inches in diameter driven ten feet into sand.

COST OF PROPOSED LITTLE SAND CREEK DEBRIS DAM

Item	Unit	Quantity	Unit cost	Item cost	Total cost
Structures—					
Pipe and wire dams	Dam	2	$1,030 00	$2,060	
Concrete dam				14,100	$16,160
Base cost					$16,160
Administration, engineering and contingencies			25 per cent		4,040
Interest during construction					0
Grand total					$20,200

PROPOSED SAND CREEK DEBRIS DAM*

Dam Construction.

Concrete gravity overflow dam on bedrock rising to bottom of present channel. Estimated height, 20 feet. Length, 160 feet.

Pipe and Wire Debris Barriers.

Twenty-foot pipe 3.25 inches in diameter driven ten feet into sand.

COST OF PROPOSED SAND CREEK DEBRIS DAM

Item	Unit	Quantity	Unit cost	Item cost	Total cost
Structures—					
Pipe and wire dams	Dam	4	$1,465 00	$5,860	
Concrete dam				14,640	$20,500
Base cost					$20,500
Administration, engineering and contingencies			25 per cent		5,100
Interest during construction					0
Grand total					$25,600

* See Plate XIII.

PROPOSED CITY CREEK PROTECTION WORKS*

Protection Levee.

Length, 15,300 feet. Top width, ten feet. Side slopes, two to one and three to one. Height, six feet above ground surface.

Diversion Levee.

Diverts creek south to river. Top width, ten feet. Side slopes two to one and three to one. Height, twelve feet above ground surface. Length, 3300 feet. Gate structures for spreading. Plans shown in Plate XII.

COST OF PROPOSED CITY CREEK PROTECTION WORKS

Item	Unit	Quantity	Unit cost	Item cost	Total cost
Earth work—					
Soil	Cubic yards	143,700	$0 20	$28,740	$28,740
Structures—					
Gates		2	1,000 00	$2,000	2,000
Base cost					$30,740
Administration, engineering and contingencies			25 per cent		7,685
Right of way					11,075
Interest during construction					0
Grand total					$49,500

PROPOSED SANTA ANA RIVER SPREADING WORKS*

Area of spreading grounds, 1230 acres. Type of spreading, ponding and channels. Cost of works estimated on acreage basis from cost records of existing works.

COST OF PROPOSED SANTA ANA RIVER SPREADING WORKS

Item	Unit	Quantity	Unit cost	Item cost	Total cost
Earth work and structures complete	Acre	1,230	$215 00	$264,450	$264,450
Base cost					$264,450
Administration, engineering and contingencies			25 per cent		66,115
Interest during construction at 6 per cent					19,835
Grand total					$350,400

* See Plate X.

PROPOSED SANTA ANA RIVER DEBRIS DAM*

This dam would be located 900 feet above the Mentone gaging station near the Mentone power house. Principal features are as follows:

Elevation, stream bed	2,015 feet
Elevation, crest	2,075 feet
Elevation, flow line	2,065 feet
Depth of storage	50 feet
Total height	60 feet
Width of top	15 feet
Length of crest	635 feet
Type of dam	rock fill
Upstream slope	1.3 :1
Downstream slope	1.4 :1
Rock—cubic yards	99,221
Type of spillway	through cut around north end of dam
Length of spillway	500 feet
Capacity of spillway	40,000 second feet
Depth of water in spillway	7 feet

COST OF PROPOSED SANTA ANA RIVER DEBRIS DAM

Item	Unit	Quantity	Unit cost	Item cost	Total cost
Dam—					
Dumped rock	Cubic yards	84,900	$1 75	$148,575	
Derrick placed rock	Cubic yards	14,330	3 50	50,155	
					$198,730
Base cost					$198,730
Administration, engineering and contingencies			25 per cent		49,680
Interest during construction at 6 per cent					7,390
Grand total					$255,800

NOTE.—This dam is proposed at lowest favorable point to check debris in connection with spreading and flood control. When filled with debris it may be found possible to raise it. If not, another dam could be placed at a favorable point upstream.

PROPOSED SANTA ANA RIVER BANK PROTECTION †

Channel Improvement.

Length, 36,700 feet flexible revetment. South bank protected from city limits of Redlands 25,000 feet westward. North bank protected from Pacific Electric bridge 11,700 feet eastward.

COST OF PROPOSED SANTA ANA RIVER BANK PROTECTION

Item	Unit	Quantity	Unit cost	Item cost	Total cost
Revetment in place—					
South bank, one row	Lineal feet	25,000		$88,000	
North bank, two rows		11,700		82,370	
					$170,370
Base cost					$170,370
Administration, engineering and contingencies			25 per cent		42,590
Interest during construction at 6 per cent					6,340
Grand total					$219,300

* See Plates X and XIII.

† See Plate X.

PROPOSED EXTENSION OF MILL CREEK SPREADING WORKS*

Diversion dam to be repaired. Protection levee to be built below spreading grounds. Length, 14,520 feet. Height, six feet. Shown in Plate XI.

COST OF PROPOSED EXTENSION OF MILL CREEK SPREADING WORKS

Item	Unit	Quantity	Unit cost	Item cost	Total cost
Earth work—					
Coarse gravel	Cubic yards	80,700	$0 30	$24,200	$24,200
Structures—					
Diversion dam				$10,000	10,000
Base cost					$34,200
Administration, engineering and contingencies			25 per cent		8,600
Interest during construction					0
Grand total					$42,800

PROPOSED SAN TIMOTEO CREEK CHANNEL PROTECTION*

Channel Improvements.

Double levees 23,200 feet long. Side slopes, two to one on land side and three to one on stream side. Height, six feet above average ground.

Debris Checks.

Three are proposed in vicinity of Redlands to stop debris movement.

COST OF PROPOSED SAN TIMOTEO CREEK CHANNEL PROTECTION

Item	Unit	Quantity	Unit cost	Item cost	Total cost
Earth work—					
Sandy loam	Cubic yards	255,500	$0 15	$38,325	$38,325
Debris dams—					
Concrete		3	10,000 00	$30,000	30,000
Base cost					$68,325
Administration, engineering and contingencies		68,325	25 per cent		17,080
Interest during construction at 6 per cent					2,595
Right of way					52,800
Grand total					$140,800

* See Plate X.

FORKS RESERVOIR ON SANTA ANA RIVER*

Capacity 6,000 Acre-feet

Principal Features

Elevation, stream bed	3,300 feet	Area of reservoir	78 acres
Elevation, crest	3,496 feet	Cost per acre-foot, storage	$497
Elevation, flow line	3,491 feet	Upstream slope	vertical
Maximum depth of excavation	95 feet	Downstream slope	3.4:1
Total height	291 feet	Depth of water in spillway	8 feet
Type of dam	concrete gravity	Length of spillway	327 feet
Thickness of crest	30 feet	Spillway equipment	6 54-ft. drum gates
Type of spillway	over dam	Length of crest	540 feet
Capacity, spillway	24,600 second-feet		
Capacity outlets	2,000 second-feet		

COST OF FORKS RESERVOIR ON THE SANTA ANA RIVER

(Capacity 6,000 acre-feet)

Item	Item cost	Total cost
Exploration		$20,000
Diversion during construction		20,000
Clearing reservoir		7,000
Dam and spillway—		
Excavation	$323,200	
Concrete	1,617,400	
Spillway	91,700	
Drilling and grouting holes, drainage holes	12,400	
Sluice gates	17,000	
		2,061,700
Lands and improvements flooded		10,000
Miscellaneous		91,700
Base cost		$2,210,400
Administration, engineering and contingencies, 25 per cent		552,600
Interest during construction		231,000
Grand total		$2,994,000

* See Plates II and XV.

FORKS RESERVOIR ON SANTA ANA RIVER*

Capacity 10,000 Acre-feet

Principal Features

Elevation, stream bed	3,300 feet	Capacity, outlets	2,000 second-feet
Elevation, crest	3,543 feet	Area of reservoir	112 acres
Elevation, flow line	3,538 feet	Cost per acre-foot	$436
Maximum depth of excavation	95 feet	Upstream slope	vertical
Total height	338 feet	Downstream slope	3.4 :1
Type of dam	concrete gravity	Depth of water in spillway	8 feet
Thickness of crest	30 feet	Length of spillway	327 feet
Type of spillway	over dam	Spillway equipment	6 54-ft. drum gates
Capacity, spillway	24,600 second-feet	Length of crest	680 feet

COST OF FORKS RESERVOIR ON THE SANTA ANA RIVER

(Capacity 10,000 acre-feet)

Item	Item cost	Total cost
Exploration		$20,000
Diversion during construction		20,000
Clearing reservoir		7,000
Dam and spillway—		
Excavation	$395,000	
Concrete	2,559,700	
Spillway	91,700	
Drilling and grouting holes, drainage holes	15,700	
Sluice gates	17,000	
		3,079,100
Lands and improvements flooded		10,000
Miscellaneous		91,600
Base cost		$3,227,700
Administration, engineering and contingencies, 25 per cent		806,900
Interest during construction		337,400
Grand total		$4,372,000

* See Plates II and XV.

FORKS RESERVOIR ON SANTA ANA RIVER*

Capacity 14,000 Acre-feet

Principal Features

Elevation, stream bed	3,300 feet	Capacity, outlets	2,000 second-feet
Elevation, crest	3,578 feet	Area of reservoir	137 acres
Elevation, flow line	3,573 feet	Cost per acre-foot, storage	$421
Maximum depth of excavation	95 feet	Upstream slope	vertical
Total height	373 feet	Downstream slope	3.4 :1
Type of dam	concrete gravity	Depth of water in spillway	8 feet
Type of spillway	over dam	Length of spillway	327 feet
Spillway equipment	6-54-ft. drum gates	Length of crest	870 feet
Capacity, spillway	24,600 second-feet		

COST OF FORKS RESERVOIR ON THE SANTA ANA RIVER

(Capacity of 14,000 acre-feet)

Item	Item cost	Total cost
Exploration		$20,000
Diversion during construction		20,000
Clearing reservoir		9,000
Dam and spillway—		
Excavation	$475,000	
Concrete	3,607,200	
Spillway	91,700	
Drilling and grouting holes, drainage holes	20,000	
Sluice gates	17,000	
		4,210,900
Lands and improvements flooded		10,000
Miscellaneous		91,600
Base cost		$4,361,500
Administration, engineering and contingencies, 25 per cent		1,090,400
Interest during construction		456,300
Grand total		$5,908,200

* See Plates II and XV.

FILIREA RESERVOIR ON SANTA ANA RIVER*

Capacity 4,000 Acre-feet

Principal Features

Elevation, stream bed	4,212 feet	Capacity, outlets	2,000 second-feet
Elevation, crest	4,390 feet	Area of reservoir	77.5 acres
Elevation, flow line	4,385 feet	Cost per acre-foot	$423
Depth of water	173 feet	Upstream slope	vertical
Depth of excavation	15 feet	Downstream slope	3.4 :1
Total height	193 feet	Depth of water in spillway	3 feet
Type of dam	concrete gravity	Auxiliary dam height	6 feet
Width of crest	20 feet	Length of spillway	630 feet
Type of spillway	separate channel	Length of dam crest	460 feet
Capacity, spillway	10,800 second-feet		

COST OF FILIREA RESERVOIR ON SANTA ANA RIVER

(Capacity 4,000 acre-feet)

Item	Item cost	Total cost
Exploration		$10,000
Diversion during construction		3,000
Clearing reservoir		3,000
Dam and spillway and auxiliary dam—		
Excavation	$266,400	
Concrete	819,100	
Spillway and auxiliary dam	87,400	
Drilling and grouting holes, drainage holes	10,600	
Sluice ways	17,000	
		1,200,500
Lands and improvements flooded		1,000
Miscellaneous		60,000
Base cost		$1,277,500
Administration, engineering and contingencies, 25 per cent		319,400
Interest during construction at 6 per cent		96,100
Grand total		$1,693,000

* See Plates II and XV.

PUBLICATIONS OF THE

DIVISION OF WATER RESOURCES

DEPARTMENT OF PUBLIC WORKS

STATE OF CALIFORNIA

When the Department of Public Works was created in July, 1921, the State Water Commission was succeeded by the Division of Water Rights, and the Department of Engineering was succeeded by the Division of Engineering and Irrigation in all duties except those pertaining to State Architect. Both the Division of Water Rights and the Division of Engineering and Irrigation functioned until August, 1929, when they were consolidated to form the Division of Water Resources.

STATE WATER COMMISSION

First Report, State Water Commission, March 24 to November 1, 1912.
Second Report, State Water Commission, November 1, 1912, to April 1, 1914.
*Biennial Report, State Water Commission, March 1, 1915, to December 1, 1916.
Biennial Report, State Water Commission, December 1, 1916, to September 1, 1918.
Biennial Report, State Water Commission, September 1, 1918, to September 1, 1920.

DIVISION OF WATER RIGHTS

*Bulletin No. 1—Hydrographic Investigation of San Joaquin River, 1920–1923.
*Bulletin No. 2—Kings River Investigation, Water Master's Reports, 1918–1923.
*Bulletin No. 3—Proceedings First Sacramento-San Joaquin River Problems Conference, 1924.
*Bulletin No. 4—Proceedings Second Sacramento-San Joaquin River Problems Conference, and Water Supervisor's Report, 1924.
Bulletin No. 5—San Gabriel Investigation—Basic Data, 1923–1926.
Bulletin No. 6—San Gabriel Investigation—Basic Data, 1926–1928.
Bulletin No. 7—San Gabriel Investigation—Analysis and Conclusions, 1929.
*Biennial Report, Division of Water Rights, 1920–1922.
*Biennial Report, Division of Water Rights, 1922–1924.
Biennial Report, Division of Water Rights, 1924–1926.
Biennial Report, Division of Water Rights, 1926–1928.

DEPARTMENT OF ENGINEERING

*Bulletin No. 1—Cooperative Irrigation Investigations in California, 1912–1914.
*Bulletin No. 2—Irrigation Districts in California, 1887–1915.
Bulletin No. 3—Investigations of Economic Duty of Water for Alfalfa in Sacramento Valley, California, 1915.
*Bulletin No. 4—Preliminary Report on Conservation and Control of Flood Waters in Coachella Valley, California, 1917.
*Bulletin No. 5—Report on the Utilization of Mojave River for Irrigation in Victor Valley, California, 1918.
*Bulletin No. 6—California Irrigation District Laws, 1919 (now obsolete).
Bulletin No. 7—Use of water from Kings River, California, 1918.
*Bulletin No. 8—Flood Problems of the Calaveras River, 1919.
Bulletin No. 9—Water Resources of Kern River and Adjacent Streams and Their Utilization, 1920.
*Biennial Report, Department of Engineering, 1907–1908.
*Biennial Report, Department of Engineering, 1908–1910.
*Biennial Report, Department of Engineering, 1910–1912.
*Biennial Report, Department of Engineering, 1912–1914.
*Biennial Report, Department of Engineering, 1914–1916.
*Biennial Report, Department of Engineering, 1916–1918.
*Biennial Report, Department of Engineering, 1918–1920.

* Reports and Bulletins out of print. These may be borrowed by your local library from the California State Library at Sacramento, California.

DIVISION OF WATER RESOURCES

Including Reports of the Former Division of Engineering and Irrigation

*Bulletin No. 1—California Irrigation District Laws, 1921 (now obsolete).
*Bulletin No. 2—Formation of Irrigation Districts, Issuance of Bonds, etc., 1922.
Bulletin No. 3—Water Resources of Tulare County and Their Utilization, 1922.
Bulletin No. 4—Water Resources of California, 1923.
Bulletin No. 5—Flow in California Streams, 1923.
Bulletin No. 6—Irrigation Requirements of California Lands, 1923.
*Bulletin No. 7—California Irrigation District Laws, 1923 (now obsolete).
*Bulletin No. 8—Cost of Water to Irrigators in California, 1925.
Bulletin No. 9—Supplemental Report on Water Resources of California, 1925.
*Bulletin No. 10—California Irrigation District Laws, 1925 (now obsolete).
Bulletin No. 11—Ground Water Resources of Southern San Joaquin Valley, 1927.
Bulletin No. 12—Summary Report on the Water Resources of California and a Coordinated Plan for Their Development, 1927.
Bulletin No. 13—The Development of the Upper Sacramento River, containing U. S. R. S. Cooperative Report on Iron Canyon Project, 1927.
Bulletin No. 14—The Control of Floods by Reservoirs, 1928.
*Bulletin No. 18—California Irrigation District Laws, 1927 (now obsolete).
Bulletin No. 18—California Irrigation District Laws, 1929 Revision.
Bulletin No. 19—Santa Ana Investigation, Flood Control and Conservation (with packet of maps), 1928.
Bulletin No. 20—Kennett Reservoir Development, an Analysis of Methods and Extent of Financing by Electric Power Revenue, 1929.
*Bulletin No. 21—Irrigation Districts in California, 1929.
Bulletin No. 21-A—Report on Irrigation Districts in California for the Year 1929, 1930.
Bulletin No. 22—Report on Salt Water Barrier (two volumes), 1929.
Bulletin No. 23—Report of Sacramento-San Joaquin Water Supervisor, 1924–1928.
Bulletin No. 24—A Proposed Major Development on American River, 1929.
Bulletin No. 28-A—Industrial Survey of Upper San Francisco Bay Area, 1930.
Bulletin No. 31—Santa Ana River Basin, 1930.
Bulletin No. 32—South Coastal Basin, a Cooperative Symposium, 1930.
Biennial Report, Division of Engineering and Irrigation, 1920–1922.
Biennial Report, Division of Engineering and Irrigation, 1922–1924.
Biennial Report, Division of Engineering and Irrigation, 1924–1926.

COOPERATIVE AND MISCELLANEOUS REPORTS

*Report of the Conservation Commission of California, 1912.
*Irrigation Resources of California and Their Utilization (Bul. 254, Office of Exp. U. S. D. A.) 1913.
*Report, State Water Problems Conference, November 25, 1916.
*Report on Pit River Basin, April, 1915.
*Report on Lower Pit River Project, July, 1915.
*Report on Iron Canyon Project, 1914.
*Report on Iron Canyon Project, California, May, 1920.
*Sacramento Flood Control Project (Revised Plans), 1925.
Report of Commission Appointed to Investigate Causes Leading to the Failure of St. Francis Dam, 1928.
Report of the Joint Committee of the Senate and Assembly Dealing With the Water Problems of the State, 1929.

PAMPHLETS

Rules and Regulations Governing the Supervision of Dams in California, 1929.
Water Commission Act with Latest Amendments Thereto, 1929.
Rules and Regulations Governing the Appropriation of Water in California, 1929.
Rules and Regulations Governing the Determination of Rights to Use of Water in Accordance with the Water Commission Act, 1925.
Tables of Discharge for Parshall Measuring Flumes, 1928.
General Plans, Specifications and Bills of Material for Six and Nine Inch Parshall Measuring Flumes, 1930.

* Reports and Bulletins out of print. These may be borrowed by your local library from the California State Library at Sacramento, California.

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